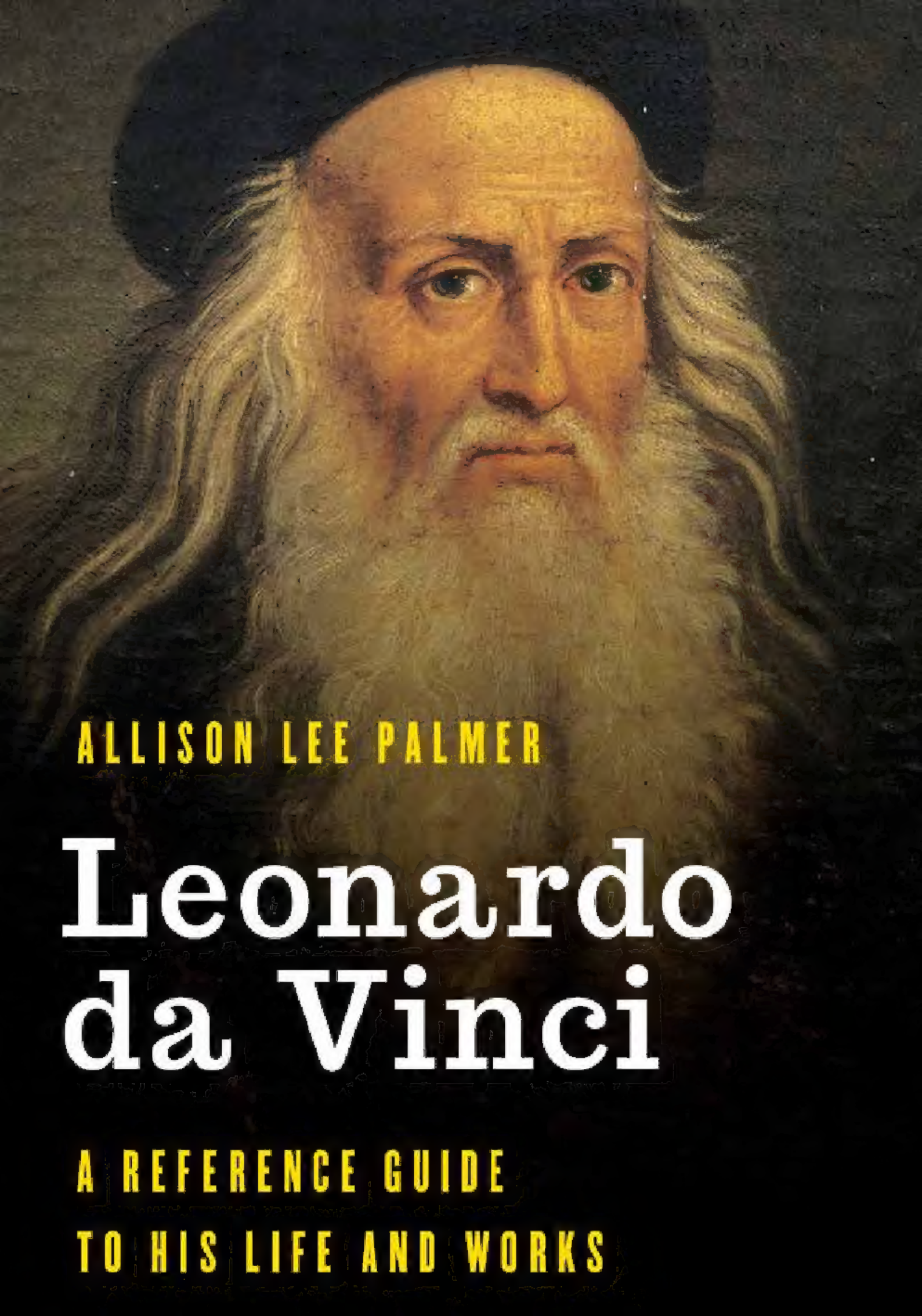


ALLISON LEE PALMER

Leonardo da Vinci

A REFERENCE GUIDE TO HIS LIFE AND WORKS

Leonardo da Vinci

Significant Figures in World History

Charles Darwin: A Reference Guide to His Life and Works,
by J. David Archibald, 2019.

Leonardo da Vinci: A Reference Guide to His Life and Works,
by Allison Lee Palmer, 2019.

Robert E. Lee: A Reference Guide to His Life and Works,
by James I. Robertson Jr., 2019.

Leonardo da Vinci

A Reference Guide to His Life and Works

Allison Lee Palmer

ROWMAN & LITTLEFIELD
Lanham • Boulder • New York • London

Published by Rowman & Littlefield
An imprint of The Rowman & Littlefield Publishing Group, Inc.
4501 Forbes Boulevard, Suite 200, Lanham, Maryland 20706
www.rowman.com

Unit A, Whitacre Mews, 26-34 Stannary Street, London SE11 4AB

British Library Cataloguing in Publication Information Available

Library of Congress Cataloging-in-Publication Data

Names: Palmer, Allison Lee, 1963– author.
Title: Leonardo da Vinci : a reference guide to his life and works / Allison Lee Palmer.
Description: Lanham : Rowman & Littlefield, 2018. | Series: Significant figures in world history | Includes bibliographical references and index.
Identifiers: LCCN 2018033651 (print) | LCCN 2018033975 (ebook) | ISBN 9781538119785 (electronic) | ISBN 9781538119778 (cloth : alk. paper)
Subjects: LCSH: Leonardo, da Vinci, 1452–1519—Encyclopedias.
Classification: LCC N6923.L33 (ebook) | LCC N6923.L33 P34 2018 (print) | DDC 709.2—dc23
LC record available at https://lccn.loc.gov/2018033651

The paper used in this publication meets the minimum requirements of American National Standard for Information Sciences—Permanence of Paper for Printed Library Materials, ANSI/NISO Z39.48-1992.

Printed in the United States of America

Contents

Preface

The entries in this volume on Leonardo da Vinci cover every aspect of his life and work, beginning with his paintings, including several he never completed, that form the core of his artistic oeuvre. These paintings are wood panels and wall murals that focus on religious subjects, for example, the *Last Supper*, and portraiture, including his famous *Mona Lisa*. Also included in this encyclopedia are several works not universally accepted by scholars as Leonardo paintings, for instance, two recent attributions that have garnered international attention and very high prices on the art market. Leonardo's oeuvre will perhaps never be fully known since most artists did not sign their works in the Renaissance, but new technical advances are giving historians and scientists the opportunity to work together to study the microscopic details of these paintings to learn more about their materials and application. Several paintings done by Leonardo's teacher, Andrea del Verrocchio, similar in style to Leonardo's early works are included here, as are entries for a group of Leonardo's students and followers, called the "Leonardeschi," who adopted his late style. There are also entries on Leonardo's significant stylistic and technical advances in linear perspective, his new use of sfumato and his innovative use of color, as well as entries on his cartoons for lost or incomplete paintings and his plans for bronze sculptures never cast.

The majority of Leonardo's work, however, consists of his annotated sketches gathered together in notebooks, where he sought to better understand the world through scientific observation. More than 6,000 folios of drawings chart his interests in many different disciplines, including geometry, chemistry, astronomy, geology, anatomy and physiology, optics, music, and plant and animal studies. He hoped to publish treatises on painting, motion, and perspective, among other topics, but died before he could gather together the pages of his notebooks in thematic order. Today, these notebooks are bound into codices held in archives and libraries throughout Europe and the United States. These sketches have been studied extensively, and they reveal many of Leonardo's practical inventions, including his flying machine, anemometer, tank, diving suit, helicopter, giant crossbow, and triple barrel cannon. While Leonardo seemed to be a pacifist, many of his inventions were in the area of military engineering, but he was also interested in practical things used in industry, some of which include his designs for quick cooling furnaces and solar power.

Leonardo was born in Florence at a time of great prosperity and incredible intellectual growth, and his own interests and skills were informed by the artistic advances of the early 1400s, as well as the culture of humanist scholarship promoted by such patrons as the Medici family. Entries are included on Leonardo's main patrons, the major places he worked, and the artists and scholars whose work and ideas played an important role in the formation of his career. Leonardo anticipated many scientific advances that were fully developed in later centuries, so there are entries on the major scientists influenced by Leonardo, as well as the scholars who first wrote about

Leonardo during his lifetime. There are also entries on artists who depicted Leonardo in their own paintings. Finally, the museums that regularly exhibit Leonardo's work, including modern reconstructions made of his inventions, are featured in this encyclopedia, as well as the best-known scholars who have devoted their lives to the study of Leonardo da Vinci.

Like other encyclopedias, this volume is arranged alphabetically in a series of lengthy entries for the general reader on all aspects of Leonardo, and each entry is extensively cross-referenced. Within individual entries, terms that have their own entries are in **boldface type** the first time they appear. Related terms that do not appear in the text are indicated in the *See also* cross-references at the end of individual entries. *See* refers to other entries that deal with the topic.

I dedicate this book to my son Julian Palmer, who inspired my interest in Leonardo da Vinci through his own eclectic studies and keen intellect. He, too, sees the world from the top of the mountain.

Chronology

1452 15 April: Leonardo is born in Anchiano, outside Vinci, to Ser Piero di Antonio da Vinci (b. 1426) and a peasant woman named Caterina Lippi (b. c. 1437). That same year, Leonardo's father marries Albiera di Giovanni Amadori (c. 1436–1465).

1457 Leonardo's mother marries local farmer Antonio di Piero de Vacca, and Leonardo is documented as living in his father's house in Vinci.

c. 1467/1469 Leonardo begins an apprenticeship in the bottega (workshop) of Andrea del Verrocchio in Florence.

1468 After the death of his first wife in 1465, Leonardo's father marries Francesca di Giovanni Lanfredini (b. 1448).

1469 Leonardo's father is documented as renting a house on Via dei Gondi in Florence, presumably for Leonardo to live in during his studies.

1472 Leonardo is accepted into the painter's Guild of Saint Luke in Florence.

1473 5 August: Leonardo's first dated work, the *Arno Valley Landscape*, reveals his early interest in scientifically rendered landscape perspectives.

1476 9 April: An anonymous denouncement is made against Leonardo and three other men, who are accused of sodomy with Jacopo d'Andrea Saltarelli (b. 1459), a studio assistant and male model. Charges were later dropped.

1476–1482 First Florentine Period. Leonardo works as an independent artist in Florence painting the *Annunciation*, thought to be his first independent work, and completes the angel on Andrea del Verrocchio's *Baptism of Christ*. He also paints portraits, including the *Ginevra de' Benci* and Madonna and Child images, for example, the generally accepted *Benois Madonna*. He left two unfinished works, the *Adoration of the Magi* and *Saint Jerome in the Wilderness*, when he moved to Milan.

1478 January: Leonardo receives his first major commission for an altarpiece for the Chapel of the Priors, dedicated to Saint Bernard, in the Palazzo Vecchio in Florence. The painting was never completed and does not exist today.

1480 The Anonimo Gaddiano notes that Leonardo is living in the Medici Palace and given work space in the garden of Piazza San Marco in Florence.

1481 March: Leonardo receives a commission for a large altarpiece of the *Adoration of the Magi* for San Donato a Scopeto, a monastery outside Florence. He never completes this altarpiece, which is in the Uffizi Gallery in Florence, nor does he finish an unknown altarpiece of Saint Hieronymous.

1482 Leonardo moves to Milan after being sent there by Lorenzo de' Medici bearing gifts, one of which is a silver lyre made by Leonardo, to help negotiate peace with Lodovico Sforza. Lodovico hires him as an artistic and engineering advisor.

1482–1499 First Milanese Period. Leonardo works at the Sforza Court in Milan.

1483 Leonardo receives a commission for the *Virgin of the Rocks*, together with Ambrogio and Evangelista de Predis. It is likely completed by 1486.

1485 Leonardo is sent to Hungary by Lodovico Sforza to meet Matthias Corvinus, the king of Hungary, who maintained one of the largest royal libraries in Europe and established a more progressive, clearer law code called the Diet of 1485.

1487–1488 Leonardo works as a construction advisor for the Milan Cathedral.

1489–1494 Leonardo works on a colossal equestrian sculpture of Francesco I Sforza called the *Gran Cavallo*, and the clay scale model is completed by 1492. During this same time, Leonardo paints court portraits of Cecilia Gallerani and Lucrezia Crivelli, and designs festival settings.

1490 Leonardo's assistant, Andrea Salaì, is hired and remains with Leonardo throughout the rest of his life.

1493 The clay scale model of Leonardo's equestrian monument is put on public display for the marriage of Emperor Maximilian to Bianca Maria Sforza but is eventually destroyed in 1499, during the French invasion of Milan.

1494 Lodovico Sforza supports King Charles VIII in his march into Italy with the French Army. This begins the Italian Wars, a series of conflicts between city-states, republics, the papacy, and the Habsburg and Valois aristocracies, lasting until 1559.

1495 Leonardo's mother dies.

1495–1498 Lodovico Sforza commissions Leonardo to paint *The Last Supper* in the Monastery of Santa Maria delle Grazie in Milan and landscapes, now largely destroyed, in the Sala delle Asse in the Castello Sforzesco.

1499 The Second Italian War (1494–1504) begins when the army of King Louis XII of France (ruled 1498–1515) marches into Milan to claim the duchy. **December:** Leonardo flees Milan with assistant Salaì and friend Luca Pacioli. They stop in Mantua in February 1500, and then go to Venice in March, where the government council seeks Leonardo's military advice on warding off a Turkish advance into Friuli.

1500–1506 **April:** Second Florentine Period. Leonardo returns to Florence.

1500 During the spring, Leonardo receives a commission for a *Virgin and Child with Saint Anne* for the Church of SS. Annunziata while living at their Servite monastery.

1501 Leonardo begins work on the *Madonna of the Yarnwinder* for Florimond Robertet, secretary to King Louis XII of France.

1502 **June:** Leonardo travels through Northern Italy for 10 months with Cesare Borgia as his military engineer, for whom he makes a *Map of Tuscany and the Chiana Valley* and *Map of Imola*, Borgia's stronghold.

1503 **Spring:** Leonardo returns to Florence and is hired to survey the Arno River to explore the possibility of diverting the river from Pisa to deprive the city from sea access, while building a canal to connect Florence to the sea. **March:** Leonardo receives a commission from Francesco del Giocondo, for a portrait painting of his wife Lisa. This is likely the *Mona Lisa* in the Louvre Museum in Paris. **18 October:** Leonardo rejoins the Guild of St. Luke, and that same month he begins the *Battle of Anghiari* mural in the Palazzo Vecchio in Florence.

1504 Leonardo's father dies; Leonardo is part of an advisory committee formed to decide where to relocate Michelangelo's *David* sculpture; Leonardo travels to Piombino with Jacopo IV Appiani to provide advice on reinforcing the castle and moat and make designs for new bastions and tunnels. Most of these drawings are in the *Codex Atlanticus*.

1506 Francesco Melzi enters Leonardo's household and remains with him throughout the rest of his life. He becomes Leonardo's heir. **May:** Leonardo receives permission to leave Florence for three months to work for Charles d'Amboise, the French governor of Milan. He never completes the *Battle of Anghiari* mural in the Palazzo Vecchio in Florence, which had been plagued by technical problems.

1506–1513 Second Milanese Period Leonardo is documented as living in the neighborhood of Santa Babila near the eastern city gate of Milan. During this time, he designs the Trivulzio Monument and continues work on his anatomical studies and scientific experiments.

1507–1508 Leonardo travels to Florence twice to resolve his father's estate with his half-siblings, the children of his father's third wife, Margherita di Guglielmo, and fourth wife, Lucrezia Cortigiani. While there, he helps Giovanni Francesco Rustici cast his bronze statues for the Florence Baptistery.

1508 August: Leonardo finishes the second version of the *Virgin of the Rocks*, now in the National Gallery in London.

1511 Charles d'Amboise dies, and the French are expelled from Milan in 1512.

1513–1516 September: Leonardo moves to Rome to work for his new patron, Giuliano de' Medici, the brother of Pope Leo X. He lives in the Belvedere at the Vatican. During this time, he works mainly on his scientific experiments, notably a plan to reclaim the Pontini marshland south of Rome. He completes his final painting, *Saint John the Baptist*, while in Rome.

1515 October: The newly crowned King Francis I of France recaptures Milan. **19 December:** Leonardo attends a meeting between Francis I, king of France (ruled 1515–1547), and Pope Leo X in Bologna, where he is commissioned to make a robotic lion for Francis.

1516 March: Giuliano de' Medici dies, leaving Leonardo without a patron. That winter, King Francis I invites Leonardo to France to work as his court painter and engineer.

1516–1519 Leonardo moves to France and is given a manor house called Clos Lucé near the king's royal château in Amboise.

1517 Cardinal Luigi d'Aragona visits Leonardo and writes about his workshop and current art projects at the Clos Luce.

1519 23 April: Leonardo writes his last will. **2 May:** Leonardo dies at the age of 67, in his bedroom at the Clos Lucé in Amboise, and is buried in the Chapel of Saint-Florentin at the Château d'Amboise. When the chapel was destroyed in 1802, Leonardo's remains were moved and reinterred at the Chapel of Saint-Hubert.

Introduction

Leonardo da Vinci is primarily considered a painter, but in his paintings and drawings he laid out a cohesive understanding of the causal relationships of the physical world. Leonardo approached the world as a scientist and believed there is a certain order to the universe that can be understood by the human mind, codified mathematically, and expressed through art. He placed a primacy on vision and wrote in his unpublished *Treatise on Painting*, "Don't you see that the eye embraces the beauty of the whole world?"

For Leonardo, the eye allows humans to study the sciences, master the arts, and create new ideas through an engagement with nature. During Leonardo's lifelong study of visual perception, he began to understand that the world consists of a web of connections, patterns, and relationships between living things, which are constantly transforming. Prior to this, Renaissance humanists based their understanding of the world primarily on the teachings of Plato and Aristotle, which they sought to integrate into the teachings of the Catholic Church. Leonardo instead developed an empirical method of acquiring knowledge that anticipated the scientific method. His notebooks, which consist of more than 6,000 pages of annotated drawings, detail his wide range of interests, including studies of the four elements, the power of nature and its movement, and the importance of the sensory experiences to the arts.[2]

Leonardo was born in a stone house in the walled hill town of Vinci, located about 30 miles outside Florence.[3] Little is known of Leonardo's mother Caterina, but she could be Caterina di Meo Lippi, a 15-year-old girl who lived in a modest farmhouse in the hamlet of Anchiano, a mile outside of Vinci, with a grandmother who died shortly before Leonardo was born. Leonardo's father was 25-year-old Ser Piero Fruosonio di Antonio da Vinci, a notary from a minor noble family in Vinci, a commune under Florentine jurisdiction. Leonardo's grandfather's family had been active in Florentine politics since the late Middle Ages and owned farmland and businesses near Vinci, while his grandmother's family owned ceramic kilns in the town of Bacchereto, across the wooded Montalbano hills from Vinci. The Medici family owned a hunting lodge in Bacchereto, where they purchased the famous cobalt-blue majolica produced there for the Hospital of Santa Maria Nuova in Florence.

Although much has been written about the burgeoning urban life in Renaissance Italy, it was the surrounding countryside that offered the natural resources used to produce goods purchased and traded throughout the region. A city, therefore, was only as strong as its surrounding rural communities, and the communities around Florence provided a network of robust local industry, which Leonardo was exposed to at an early age. Leonardo's childhood travels between city and country, then, were some of the earliest ways he interacted with the world around him.

Although Leonardo's father Ser Piero had already established his career in Florence, it was customary to return home to the countryside in the summer to avoid heat-related illnesses and the stagnant air of city life, therefore, it was

outside Vinci, in midsummer of 1451, where he met Caterina. Although Leonardo's parents never married, Leonardo maintained familial relationships with both parents, as well as his half-brothers and half-sisters, throughout his life. Leonardo's paternal grandfather, Antonio, proudly announced that Leonardo was born at about 10 p.m. on the night of 15 April 1452. The accuracy of this time and date suggests Antonio and other family members were present, which would mean Leonardo was born in his father's home in Vinci rather than at his mother's home in Anchiano, as prior scholars assumed. In Vinci, Caterina would have received more nourishing food and rest during her pregnancy, which was a dangerous time in a woman's life during that time.

Furthermore, Leonardo's mother likely did not raise him, as it was more common for a child to live in his father's home with a wet nurse employed. A few months after Leonardo was born, his father married 16-year-old Albiera di Giovanni Amadori of Florence, while his family perhaps provided a dowry for Leonardo's mother Caterina to marry a local worker named Antonio, the son of baker Piero di Andrea di Giovanni Buti "del Vacca." Antonio is described in documents as a lime burner, so he would have worked at a local lime kiln making mortar and bricks.

While Caterina and Antonio eventually had five children together, Leonardo was raised by Albiera, considered a more suitable mother due to her elevated status in Florentine society, until her death during childbirth when Leonardo was 12 years old. Three years later, Ser Piero married 20-year-old Francesca, daughter of notary ser Giovanni Lanfredini of Florence, and about that same time he arranged for the young Leonardo to begin an apprenticeship in the workshop of Andrea del Verrocchio, the leading artist in Florence.

With the rise of humanism in the Renaissance, members of the nobility were encouraged to study both the arts and sciences, to be broadly educated, and to look back to their past to learn from antiquity and apply this knowledge to modern concerns. A well-rounded education included a study of Latin, as well as the seven liberal arts—arithmetic, geometry, astronomy, music theory, grammar, logic, and rhetoric—while philosophy was later introduced, including natural and moral. Natural philosophy, the study of nature and the physical world, captivated Leonardo. A university education, as well as the occupation of a notary, was out of reach for Leonardo given his illegitimate status, but this did not deter his father from seeking out a respectable career path for his son. When Leonardo was 14 years old, his father sent him to study art in the workshop of Andrea del Verrocchio, one of the leading artists in Florence, who had close ties to the Medici family. There Leonardo studied for seven years as a shop boy, and he studied with young painters Domenico Ghirlandaio, Pietro Perugino, and Sandro Botticelli, among many others, while learning how to mix pigments, prepare panels, experiment with oil paint, and calculate space and volume through shading and perspective.

Although Leonardo ultimately spent most of his life in the cities of Florence and Milan, the countryside clearly captured his early imagination and shaped his interest in landscape studies, perspective views, and cartographical and geological interests. One of Leonardo's earliest drawings and his first extant signed work is the *Arno Valley Landscape*, a pen and ink study on parchment dated 5 August 1473, depicting the mountains around Montelupo Castle seen from the top of a precipice with a sweeping view of the farmland below. This is the first pure landscape of the Italian Renaissance and depicts a view of the countryside outside Florence, devoid of human figures. This drawing was clearly more than a study for a painting background, however, as here Leonardo made careful observations of rock formations and the undulating movement of the land, together with an early example of mathematical perspective, where orthogonal lines are lightly sketching into the background tilled fields. It was in Verrocchio's workshop where Leonardo began these types of more scientific optical studies.

Most Renaissance artists were not from the noble class, but the profession of painting was increasingly elevated in the Renaissance, where a practical knowledge of geometry,

needed for their designs and compositions, and some understanding of chemistry, needed for mixing pigments and pouring molten bronze, was expanded to require the knowledge of philosophical ideas from antiquity. The rich intellectual climate in Florence and Leonardo's access to these new ideas, especially those discussions concerning nature, had a profound impact on his art career, and the confluence of scientific and artistic advances in the late Middle Ages set the stage for Leonardo's work in expanding these ideas into the areas of engineering, anatomy, geology, and cartography, among many other fields of study. The term *polymath* is a Greek word for a person who is broadly educated in a variety of different areas of study. Leonardo is frequently described as a polymath, and although he was not the first one, he was one of the best-known thinkers of the Renaissance in his ability to apply theoretical ideas toward a practical conclusion.

In 1472, Leonardo joined the Guild of Saint Luke, and his father funded his first independent workshop, where he continued to collaborate with Verrocchio, while also starting to work with the Medici family and other prominent Florentine patrons. Documents from 1476 relate that Leonardo, together with three others, was charged with sodomy, a common charge during this time, but he was acquitted, likely due to the high status of one of the accused. This issue had no real impact on his career, but it is consistently mentioned in scholarship because it offers a picture of a moment in Leonardo's life, as confirmed in primary documentation, and scholars must seek out as much extant source material as they can find to craft the fullest possible image of life during the Renaissance.

The years 1476 1482 are called Leonardo's First Florentine Period, when he established his own independent workshop. While in Verrocchio's shop, Leonardo is credited with painting one of the angels in Verrocchio's *Baptism of Christ* in about 1475, which demonstrates a mastery of shading and volume. Leonardo's *Annunciation* is his earliest surviving independent painting, dated from 1472–1476, and it is now universally attributed to him after having first been attributed to Verrocchio, an easy error given the stylistic similarity between Verrocchio's work and Leonardo's early career. Here Leonardo balances the prevailing interest in classical idealism in a work that features the elegant Virgin Mary and graceful angel Gabriel, both of whom appear in the lush garden of a country home, with a carpet of flowers in the foreground and rocky mountains rising up in the white misty background. This work shows Leonardo's ability to balance scale and depth, realism and idealism.

Leonardo also painted a series of portraits during this time period in Florence, including the *Ginevra de' Benci* and various Madonna and Child images, for example, the generally accepted *Benois Madonna*. The portrait of the young aristocratic woman Ginevra was done between 1474–1478, and was likely made to commemorate her wedding to Luigi di Bernardo Niccolini when she was 16 years old. Juniper bushes frame her face and blend in with her auburn hair, which is tied against her head, while curls frame her face. Ginevra was known for her beauty, as described in several poems written by members of the Platonic Academy, sponsored by the Medici family. Ginevra was also described as a poet, although none of her own writings exist today. In contrast, the *Benois Madonna* is a small Madonna and Child painting that shows a seated Madonna smiling and offering a small white flower to the Christ Child, who sits on her lap. The dark, restricted palette and soft, expert modeling of both the figures and their poses anticipates Leonardo's sfumato, or smokiness, which became the main stylistic trait of his paintings.

Documents speak of more works, incomplete or lost today, for instance, his first major commission in January 1478, for an altarpiece dedicated to Saint Bernard for the Chapel of the Priors at the Palazzo Vecchio in Florence, a work that doesn't exist today, and another commission he received in 1481, for a large altarpiece for San Donato a Scopeto, a monastery outside Florence. This work, the *Adoration of the Magi*, was never completed but is located at the Uffizi Gallery in Florence today and is a wonderful example of Leonardo's working method. Here we see how he began with a charcoal outline on a primed wood

panel and defined the overall composition first, and then built in the figures and objects with light and dark contrasts to reveal their varied gestures and poses. Lastly, he would have added in layers of pigment. He left another unfinished work, the *Saint Jerome in the Wilderness*, when he moved to Milan.

By 1480, an anonymous biographer noted that Leonardo was living at the Medici residence and working in the gardens of the Piazza San Marco in Florence near the Medici Palace. Indeed, the Medici were Leonardo's main patrons in the first half of his career, but this changed in 1482, when Lorenzo de' Medici commissioned Leonardo to make a silver lyre in the shape of a horse's head as a gift for his rival, Lodovico Sforza, the Duke of Milan, and Leonardo was sent to Milan to personally deliver this gift. The lyre does not exist today, but Leonardo made sketches of various musical instruments, which can be found in his notebooks, and several reconstructions have been made to show a lyre perhaps made of wood covered with hammered silver, with either a horse's skull as part of the sound box or with a decorative silver horse's head on the neck or arm of the instrument. During this visit, Leonardo offered his services to Lodovico, who hired Leonardo as his chief artistic and military engineer. This began Leonardo's First Milanese Period, during which time he worked for the Sforza court for the next 17 years, until the French Army invaded Milan in 1499.

In Milan, Leonardo was commissioned to paint some of his most famous works, including the *Virgin of the Rocks*, completed in about 1486, and the *Last Supper* mural, from 1495–1498. The *Last Supper*, despite extensive damage to the wall surface and pigments, epitomizes Leonardo's atmospheric realism blended with his number symbolism, which was used to unify the composition of this biblical scene, while also deepening the iconography of the subject. Leonardo also painted several court portraits in Milan, including those of Cecilia Gallerani and Lucrezia Crivelli. The *Lady with an Ermine*, a small painting now located in the National Museum in Kraków, was painted in about 1489–1490, and likely depicts Lodovico's mistress, Cecilia Gallerani. It is an oil-on-walnut panel about 21 x 15 inches in size that shows a half-length young woman seen in a dynamic three quarter view as she turns her head to look out of the painting and strokes the soft form of a squirming ermine, a household pet in the Milanese court. Cecilia was an important member of the court of Milan, and from her apartment in the Castello Sforzesco she sponsored literary and musical events that inspired discussions of art and philosophy.

In Milan, Leonardo was also responsible for creating stage sets and generating ideas for many different types of inventions. While Lodovico was his main patron during these years, Leonardo was free to travel into the countryside to study nature, learn human anatomy through dissections, and theorize many different types of inventions. His notebooks, the bulk of which were completed in Milan, show the breadth of Leonardo's scientific knowledge, where he made thousands of sketches of birds in flight, flying machines, flowing water, studies for canals and water diversion projects, and practical solutions for his artistic needs, for example, a furnace with a controlled flame, as well as many different pigment recipes. Lodovico also commissioned Leonardo to create new military equipment, including a wheeled wooden bridge that could be folded quickly for easy transport and a 33-barrel organ that anticipated the modern machine gun. Few of these inventions were ever built, but his drawings served as important prototypes for inventions completed in subsequent centuries. Leonardo made more than 6,000 drawings throughout his life, many of them annotated in his left-handed mirror writing, and he planned to publish several treatises, including one on painting and one on anatomy. These sketches exist today bound together in codices and held in archival collections throughout Europe and the United States.

It was in the mid-1480s when Leonardo began his habit of carrying around a pocket-sized notebook and sketching a full range of scientific observations. His studies of a human skull date to c. 1485, and by 1489, he had begun to gather his extensive collection of drawings of the human body, its proportions, anatomy and physiology, and its movement

in a treatise called "On the Human Figure." One particularly famous drawing from this group is his *Vitruvian Man* from c. 1492, now in the Accademia in Venice. This single sheet is inscribed the "proportions of a human body according to Vitruvius," which is a rare use of a specific classical source, but here Leonardo also relied on his own empirical studies. We see a nude male body measured in three basic geometric shapes—the circle, square, and triangle, with his legs first together and then apart, while his arms are straight out and then stretched upward. In each of these movements, Leonardo adjusted the length of the arms and legs, and the position of the navel, thereby correcting Vitruvius.

Leonardo was one of the earliest artists to challenge the ancient canonical studies of the human form through scientific observation, which anticipated the dramatic increase in scientific studies of the human form that began in the mid-1500s. Although scholars sometimes wonder how different history would have been had Leonardo's notebooks been published in his lifetime, his manuscript pages were widely disseminated and his ideas certainly known. For Leonardo, the study of the human body allowed for a fuller understanding of the measurement of the universe, as he intuited that human proportions were a microcosm of a larger whole. Throughout Leonardo's life, he sought to extrapolate new ideas from the things he could see and theorize new ways of understanding by comparing patterns of the known world to the unknown. It was this ability to calculate beyond human comprehension that made Leonardo an enduring genius whose ideas remain relevant today.

During these years in Milan, Leonardo lived in an old Visconti palace next to the Cathedral of Milan, where the Palazzo Reale is now located. His household consisted of several students, including Salai, who worked for Leonardo for 25 years, as well as several other assistants and a housekeeper. With the help of his workshop, Leonardo continued to test the edges of Renaissance technical abilities in another commission given to him by Lodovico Sforza for a colossal equestrian monument of Lodovico's father, Francesco Sforza. It was to be the largest horse and rider ever made, and Leonardo planned to cast the sculpture in one piece, therefore, his studies of furnaces and methods of large-scale transportation intensified during these years, while he made a clay scale model, called the *Gran Cavallo*, and studied how it could be cast upside down for best heat distribution. After elaborate plans, the bronze purchased for the monument was eventually used for canons and the project abandoned in 1499, at the French invasion of Milan, however, the horse was finally completed in 1999, for its 500-year anniversary, and it was unveiled in Milan, while a second copy is located in Grand Rapids, Michigan. Cast in 60 pieces instead of one, the horse lacks its rider but still reveals Leonardo's highly technically sophisticated design. In December 1499, Leonardo fled Milan with his assistant, Salai, and friend, mathematician Luca Pacioli. They stopped in Mantua for a month before arriving in Venice the following March 1500, and later that year they returned to Florence.

In Florence, Leonardo initiated a six-year time period called the Second Florentine Period, although during this time he continued to work for many patrons throughout Italy, including Cesare Borgia, a mercenary soldier who was the son of Pope Alexander VI. Leonardo's first commission in Florence was for his *Virgin and Child with Saint Anne*, an oil-on-wood panel, in 1500. This challenging composition depicts the Virgin Mary seated on her mother's lap while reaching forward toward the Christ Child, who stands next to them playfully grasping the ears of a lamb. This was a new subject, and it required Leonardo to stack the figures in a challenging pyramidal shape. He also worked on several smal Madonna and Child paintings, and in March 1503, he received a commission from Francesco del Giocondo for a portrait of his wife, considered to be the famous *Mona Lisa* now in the Louvre Museum in Paris. This painting depicts this young wife looking out of the painting, directly at the viewer, in a forward gaze that challenged the way women were presented to the public during this era. Here, the traditional humble downward gaze had been replaced by the eyes of a woman who seems to stare out of the painting and through

time to look directly at us, today's viewers. Her humanity has therefore transcended time and space in a way that had never been done before in female portraiture.

In 1502, Cesare Borgia, who served as commander of the papal armies, led his men against the Sforza of Milan, in alliance with the king of France. During this time, Leonardo traveled throughout Northern Italy for 10 months, surveying land and drawing maps, including the *Map of Imola*, which is the first known ichnographic map, seen from a single point of view above that creates a perpendicular aerial view much like how Google Earth maps are made today. Borgia's troops had conquered Imola, which became his stronghold in Northern Italy. Thus, he needed a map that could approximate the distance between buildings with accurate measurements of streets and building sizes. Leonardo then returned to Florence, where he intensified his water studies while surveying the Arno River to explore the possibility of diverting water from Pisa. Although this project remained unfulfilled, his water studies laid the foundation for important observations about fluid dynamics and surface tension, informing later scientists.

Later that year, Leonardo was commissioned by Pietro Soderini to paint a large wall mural of the *Battle of Anghiari*, which was never completed due to technical problems. Leonardo attempted to use oil paint, but the paint could not dry fast enough and dripped off the surface. The damp intonaco also grew mold, and the room had to be replastered. During this time, Michelangelo was working across from Leonardo on his mural of the *Battle of Cascina*. Neither mural was completed, but both Leonardo and Michelangelo made cartoons of their compositions, known today in later copies. One can wonder how the two men worked together in this large audience hall, day after day, until both murals were abandoned, as Michelangelo returned to Rome, while Leonardo returned to Milan.

In Milan in 1506, now for the Second Milanese Period, Francesco Melzi joined Leonardo's workshop and stayed with him until his death. It was during this time period that Leonardo began to train many students, including Bernardino Luini and Marco d'Oggiono, in his sfumato style of painting, which became widely popular throughout Italy and into Spain and Flanders. By 1508, Leonardo was living in a house in the west side of the city, near the Church of Santa Babila. There he worked for the French governor of Milan while continuing his notebook studies and unfinished paintings, including the *Mona Lisa*. He also revived his horse studies with a bronze equestrian monument commissioned by General Giangiacomo Trivulzio, which was planned to include a more technically challenging pose with the two front legs rearing up. This sculpture also exists only in drawings and a possible maquette, as it was never cast.

Milan was not the same city it had been with the vibrant Sforza court, which provided a rich intellectual culture and numerous art commissions. During these years, Leonardo returned to Florence frequently to work out his father's will, and in 1513, he was invited to Rome by Giuliano de' Medici, the brother of Giovanni de' Medici, the newly elected Pope Leo X. Leo was a humanist scholar who had studied with Marsilio Ficino in Florence, and he likely knew the elder Leonardo from these same intellectual circles. In Rome, Leonardo was given an apartment in the Palazzo Belvedere, together with his students, Salai and Melzi. They stayed in Rome for three years, where Leonardo worked on projects to improve the city's infrastructure, and he continued his studies of water dynamics. He completed his final painting, the *Saint John the Baptist*, while in Rome. In December 1515, Leonardo went to Bologna as an advisor to Leo X to help negotiate a peace treaty with the newly crowned King Francis I of France. Francis was impressed by Leonardo's robot lion, whose chest opened up with a system of pulleys and levers to reveal the French fleur-de-lis, and with the approval of Leo X, Francis hired Leonardo as his artistic advisor.

In 1516, Leonardo moved to the country house Clos Lucé near the king's Château d'Amboise, where he spent the remaining years of his life until his death in 1519, at the age of 67. While in France, Leonardo increasingly relied on Francesco Melzi to oversee the completion of some of his projects, including a

plan for Romorantin that Leonardo envisioned as an ideal city with ambitious buildings and canals linking the Cher River to the royal palace. Water mills were to provide energy, while the canals would have been cleaned regularly. Although a theoretical city, Romorantin was important to later urban planners who sought to balance infrastructural needs with ideas on beauty, health, prosperity, and happiness. Perhaps during this time Francesco Melzi also drew the famous sketch of Leonardo, a profile view of an elderly man with a long beard, which became the image of Leonardo that endures in our minds today. Leonardo had always been described as a handsome man, interested in elegant clothing, and he did not have a beard until later in his life. Here his hair and beard are both carefully combed, and they frame his thoughtful face, staring out of the red chalk drawing.

One afternoon, Leonardo was in the process of drawing topologically equal triangles of varied shapes to derive a mathematical formula, but he abruptly stopped his work and wrote "et cetera." Then, on the next line, as a way of explaining why he quit his work, he wrote "perche la minesstra si fredda," meaning that his soup was getting cold.[4] On 2 May 1519, Leonardo fell ill and died while in bed surrounded by his students. He had written a will and left his belongings to Melzi, who sold his paintings and brought his notebooks back to Milan, while Leonardo was buried in the Chapel of Saint-Florentin in the Château d'Amboise. Back in Milan, Melzi spent the rest of his life organizing Leonardo's drawings into a series of publications that never materialized, and upon Melzi's death, his work was disassembled and the books were sold off by his heirs.

Leonardo lived during the time of humanism, when scholars looked back to antiquity to better understand humankind's place in the world. This cultural movement coincided with an era of great prosperity, when public and private patrons leveraged the arts to educate the public and promote their authority. Artists were also beginning to position themselves among educated patrons and scholars to access the latest innovations and ideas. The generation of artists living in Florence before Leonardo initiated the study of perspective and optics in their quest for greater realism in painting, sought new technical advances in monumental sculpture, and brought back ancient architectural models while introducing new advances in structural engineering. Leonardo transformed these innovations in every area of the arts with his establishment of an empirical method of scientific observation. Furthermore, the desire to document this era among scholars contemporary to Leonardo has allowed historians to know quite a bit about these artistic motivations, yet so much remains unanswered.

Leonardo's life was documented in contemporary sonnets and guidebooks, and several 16th-century authors wrote his biography, one of whom was Giorgio Vasari, whose account of Leonardo's life in his *Vite de' piu eccellenti architetti, pittori et scultori*, first published in Florence in 1550, is the most extensive. While Vasari's biases continue to color how we view the Renaissance today, Leonardo's contributions are undeniable. His scientific approach to observing the world inspired numerous artistic and scientific advances in the fields of painting, sculpture, mathematics, optics, anatomy and physiology, biomechanics, engineering, chemistry, geology, and cartography. This encyclopedia seeks to provide an overview of his achievements.

NOTES

1. Fritjof Capra, *The Science of Leonardo. Inside the Mind of the Great Genius of the Renaissance* (New York. Anchor Books, 2007), p. 237.

2. See Irma Richter, *Leonardo's Notebooks*, 2nd ed., edited by Thereza Wells and a preface by Martin Kemp (Oxford: Oxford University Press, 1980), first published in 1952, for this organization.

3. Recent biographies include Walter Isaacson, *Leonardo da Vinci* (New York. Simon and Schuster, 2017) and Charles Nicholl *Leonardo da Vinci Flights of the Mind* (London. Penguin, 2005), while Martin Kemp, *Leonardo da Vinci, the Marvelous Works of Nature and Man* (Cambridge, Mass.: Harvard University Press, 1981) and Kenneth Clark *Leonardo da Vinci* (London: Phaidon, 1954) remain relevant and have been published in numerous later editions.

4. Isaacson, *Leonardo da Vinci*, 511.

Entries A–Z

A

ACOUSTICS. *See* MUSIC; OPTICS.

ADAM AND EVE. This lost work, a watercolor drawing for a tapestry, was described by **Giorgio Vasari** and **Anonimo Gaddiano**, both of whom likely saw this full-sized drawing in the collection of Ottaviano de' **Medici** (1484–1546) in **Florence** in the 1540s. These two primary witnesses to Leonardo's career and artistic output have helped scholars reassemble Leonardo's oeuvre, while their observations provide valuable information about Leonardo's lost works. This was a colored drawing done to scale that would have been from Leonardo's First Florentine Period, and perhaps it was one of his first independent commissions done while working in the shop of **Andrea del Verrocchio** in the early 1470s. Vasari noted that the cartoon was to be sent to Flanders for weaving in silk and gold, and then sent as a gift to the king of Portugal, so it was perhaps a Medici gift offered to secure a role in Portugal's global trade ambitions.

Vasari described the work as featuring a verdant meadow with animals that were so realistic they must have required much patience to complete. Indeed, Leonardo was known to have begun his scientifically rendered **animal studies** during this time by dissecting horses, pigs, and birds. Scholars think the composition inspired a drawing by **Francesco di Giorgio Martini** now in the Christ Church Picture Gallery in Oxford, but otherwise little is known of the overall appearance of this work. Since the work was never finished, the cartoon would have remained in Leonardo's possession, and Vasari mentioned it was eventually in the possession of Leonardo's uncle, likely his step-uncle, Alessandro Amadori, the Canon of Fiesole, who must have given it to Ottaviano de' Medici. Leonardo perhaps gave the cartoon to his uncle in 1482, when he left Florence for **Milan**, during which time he also gave his unfinished ***Adoration of the Magi*** panel to painter Giovanni de' Benci. That year Leonardo packed up his workshop and took it to Milan, where he spent the next 17 years working for the Sforza family. *See also* DRAWINGS, PAINTINGS, SFORZA, LODOVICO.

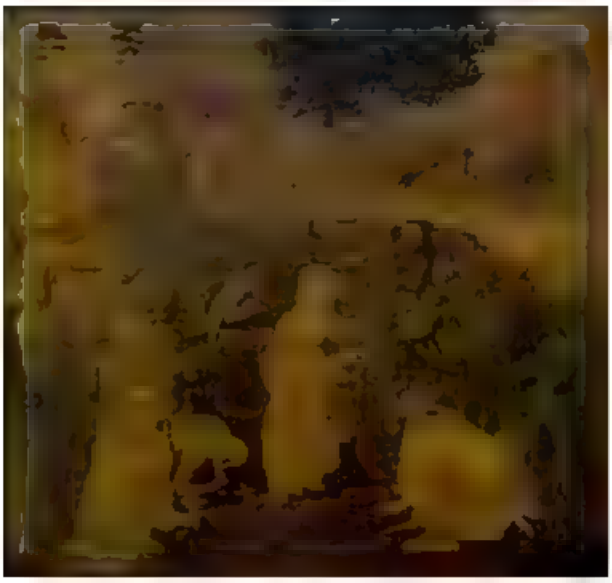
ADDING MACHINE. Leonardo theorized numerous calculating devices, many of which appear in volume 1 of his ***Madrid Codices***, considered the earliest, most comprehensive **Renaissance** treatise on mechanics. On folio 36v, the upper drawing depicts a gear system where the wheels are numbered from one to 13, going from smaller wheels to larger. Leonardo explained in an adjacent text, written in his characteristic mirror writing, that this gear system was similar to the one he designed with levers, except that the gears offered continuous movement. As each gear turns it rotates completely and goes back to zero, which triggers the second gear to move from zero to one, and so on, going across the gears to mark the carry places.

In the early 1900s, Dr. Roberto Guatelli, an Italian engineer from **Milan**, created some of the earliest working models of Leonardo's mechanical **inventions**, and these models went on a traveling exhibit funded by Benito

Mussolini. It was then that Guatelli surmised that this adding machine, or calculator, was in fact a ratio machine that would record a carry, which was not a new invention. Instead, in **Vitruvius's** *De architectura*, the ancient Roman engineer described a hodometer with a carry mechanism that Leonardo would have been familiar with, so Leonardo was perhaps trying to create a more efficient hodometer. Guatelli made a theoretical model of this machine in 1968, but scholars concluded that friction would have prevented the model from working in the Renaissance. Ultimately, Leonardo's model remains puzzling in its use of zero to 13 instead of zero to 10, while the appearance of weights at either end would not have been needed for a calculator, and no mechanism was in place to stop the machine from its continuous movement. A prototype of a mechanical calculator was eventually built in the early 1600s that combined an abacus with a pedometer, and in 1642, French mathematician Blaise Pascal (1623–1662) invented the first working mechanical calculator while calculating tax collections for his father. It remains unclear if Leonardo's early designs for numerical calculators had any lasting value for future inventors. *See also* ENGINEERING; MATHEMATICS.

ADORATION OF THE MAGI. The *Adoration of the Magi* (**Florence,** Uffizi Gallery) is an unfinished square panel painting by Leonardo that, because it is incomplete, shows Leonardo's underpainting process. This large (95.6 x 96.8 in.) **oil**-on-wood altarpiece was commissioned by the Augustinian monks of the Church of San Donato a Scopeto in Florence in 1481, but a year later Leonardo left for **Milan** and never completed the work. The composition features a seated Virgin holding the Christ Child on her lap flanked by the three kneeling Magi. The group forms a triangular composition that Leonardo repeated in many subsequent panels. On either side of this central group is a larger group of men that were part of the travel retinue of the three kings. They wear simple robes and surround the Virgin and Child, leaning in while gesturing and talking, and looking left and right in a mass of energy. These figures demonstrate Leonardo's understanding of **anatomy**, while the triangular composition recedes back in space to reveal a pyramid. A single tree grows up to the right of the central group, while the remains of an incomplete stairway appear to the viewer's left. Several horses prance and rear up impatiently in the background. A horizon line is sketched across the top third of the painting, together with a few small trees and distant clouds. The stairway fragment could reference the ruined palace of King David, Christ's ancestor, while the central tree could refer to the tree of David, while the two figures fighting in the background could have been added by Leonardo to establish a mathematical perspective for his work through the straight lines of the **architecture**.

Today we see the charcoal outlines and underdrawing for the painting, while three extant **drawings** are known to relate to the work, including a sketch of a horse and rider (Fitzwilliam Museum), a pen and ink study of the central figures (Paris, Louvre Museum), and a **perspective** study of the architecture (Florence, Uffizi Gallery). The painting, although lacking in its layers of pigment, demonstrates how Leonardo built up his figures with **light** and dark shadowing, and with a sense of smokiness, or **sfumato**, that was so characteristic of his style and anticipated the High **Renaissance**. Leonardo's preparatory drawing for the painting (pen and ink with silverpoint and white on paper, 163 x 290 mm., Florence, Uffizi Gallery) shows the space measured in a grid with lines that recede back into the center horizon to reveal Leonardo's mastery of mathematical perspective. Two sets of stairs appear on the viewer's left, one smaller than the other, to show its greater distance from the viewer, while a lightly sketched pitched roof above the center group suggests they are inside a large room. Once Leonardo left for Milan, the commission was given to Filippino Lippi (1457–1504), who completed his *Adoration of the Magi* in 1496, now in the Uffizi Gallery in Florence, while Leonardo's unfinished painting provides an important example of his early painting process. *See also* CATHOLICISM; CHIAROSCURO; LINEAR PERSPECTIVE, PAINTINGS.



Leonardo da Vinci, *Adoration of the Magi*, c. 1481, oil and tempera on panel, 95.6 x 96.8 inches, Florence, Uffizi Gallery.

AERIAL PERSPECTIVE. *See* ATMOSPHERIC PERSPECTIVE.

AERIAL SCREW. *See* AERODYNAMICS; *CODEX ON THE FLIGHT OF BIRDS*; HELICOPTER; INVENTIONS; NOTEBOOKS; *PARIS MANUSCRIPTS*.

AERODYNAMICS. Leonardo's observations of birds in flight followed the same scientific process as his **water studies**, and his hundreds of **drawings** of flying birds formed the basis for his human-powered **flying machines**. He noted that birds are like machines that must operate following scientific principles, and those principles can be translated into man-made flying machines. This idea shows that Leonardo sought to observe the underlying principles of flight, and he was therefore the first person to understand the mechanics of lift, which he observed was not due to the flapping of wings, but to a difference in pressure beneath and above the wing. While in **Milan** in the mid-1480s, Leonardo made sketches of **parachutes** and gliders, and a **helicopter** (called an aerial screw); he drew a human-powered ornithopter with flapping wings; and he made many sketches of mechanical wings.

Leonardo was fascinated with flying, also evident in his aerial view maps and **landscape** sketches. He invented the first barometer and **anemometer**, and created a parachute by modifying kite technology. He also suggested that the wings of a flying machine do not need to move, and its engine can be separate from its wings. He understood the concepts of drag and resistance, and knew that a streamlined design could reduce drag. Thus his studies of airflow were some of the first scientific studies of aerodynamics, and the Wright brothers, who made their own studies of lift and drag when inventing a fixed-wing airplane, built on Leonardo's ideas with their own. *See also CODEX ON THE FLIGHT OF BIRDS*; INVENTIONS; *PARIS MANUSCRIPTS*.

AERONAUTICS. *See* AERODYNAMICS; INVENTIONS.

ALBERTI, LEON BATTISTA (1404–1472). Florentine humanist Leon Battista Alberti is best known as an architect, but it was his broad exploration of the arts in both practical and theoretical terms that had a profound influence on Leonardo. Born into a wealthy Florentine family while in exile in Genoa, Alberti studied in Padua and Bologna before returning with his family to **Florence** in 1428. After finishing his law degree in Bologna, he preferred to follow a literary profession, accepting a position as papal secretary to Nicholas V, where he worked on **Latin** writings for the Church. In **Rome**, Alberti began his studies of antiquity. His first publication, *Della pittura*, was completed in 1435, and introduced the first codified discussion of one-point mathematical **perspective** based on the observations of Florentine architect **Filippo Brunelleschi**, who worked on the dome of the Florence Cathedral and designed the earliest **Renaissance** buildings in Florence in the new classical style.

Although Alberti relied on classical texts for his understanding of the arts, he reminded the reader that all knowledge is found in nature, and the duty of the artist is to imitate the best examples of things found in nature. Alberti's observations of the natural world and the human form, depicted in painting with

color, depth, and composition, laid the foundation for Leonardo's ideas on painting, where Leonardo followed Alberti's suggestion that painting is a science. Alberti's treatise on **architecture**, *De re aedificatoria*, 1452, was the first architectural treatise of the Renaissance, and it was inspired by **Vitruvius's** ancient Roman architectural manual from the 1st century BCE, specifically Vitruvius's notion that proper architectural proportions are derived from the human body. In addition to Leonardo's extensive scientific studies of the human body, Leonardo also looked back to Vitruvius for ideas on the ideal human form, as seen in his ***Vitruvian Man.***

Alberti's achievements were primarily theoretical, to which Leonardo added practical knowledge by gathering empirical data. Ultimately, it was Alberti who considered **mathematics** the link between art and science, and Leonardo explored this fundamental idea throughout his career. Thus, while we think of Leonardo as a universal genius, it was Alberti who epitomized the idea of a broad-based education with his studies of **music**, **Latin**, literature, mathematics, **cartography**, cryptography, and the arts. *See also* CLASSICISM; FILARETE, ANTONIO DI PIETRO AVERLINO; HUMANISM; LINEAR PERSPECTIVE; MARTINI, FRANCESCO DI GIORGIO.

ALBERTINI, FRANCESCO (1469–1510). Francesco Albertini was a Florentine artist who first studied with **Domenico Ghirlandaio** before becoming a cleric appointed canon of the Church of San Lorenzo in **Florence**, which was built for the **Medici** family behind their urban palace. He is known for writing three guidebooks: the first one in 1510, as a guide to ancient Roman monuments; the second one an updated guide to **Rome** with a fuller description of the more recent city renovations sponsored by Pope Sixtus IV in the 1480s; and the third one a guidebook to the city of Florence. Guidebooks to Rome had been written through the Middle Ages for the benefit of pilgrims traveling to St. Peter's, but this third volume, called *Memoriale di molte statue e pitture che sono nell'inclyta ciptà di Fiorentia*, was the first guidebook written of Florence, and it promoted the city as equal in its cultural standing to Rome.

Because Albertini had trained as an artist, he was knowledgeable about Florentine art, and so his account book provided valuable information, although at times factually incorrect, about the major artists in Florence before **Giorgio Vasari's** lengthier *Lives of the Artists* was published in 1550. Albertini mainly provided descriptions of the art found in major churches, convents, and palaces in Florence, and included descriptions of Leonardo and **Michelangelo's** murals in the Palazzo Vecchio, where Albertini had seen Leonardo's horse **drawings** made for the ***Battle of Anghiari*** wall mural. These descriptions provide important historical documentation of these works that were never completed. *See also* CLASSICISM; HUMANISM; PAINTINGS.

ALGEBRA. *See* GEOMETRY, MATHEMATICS.

AMBOISE, CHARLES II D' (1473–1511). Charles d'Amboise was the French governor of **Milan** from 1503–1511. Born into the House of Amboise, he was first appointed lieutenant general of Lombardy and moved to Milan in 1501. Although Leonardo had left Milan in 1499, with the loss of his patron, **Lodovico Sforza**, during the French invasion, he maintained contacts in the city, and in 1501, he was commissioned to paint the ***Madonna of the Yarnwinder*** for Florimond Robertet, the secretary to King Louis XII of France, which he completed in 1507. In 1510, Charles II led the French Army into battle against Pope Julius II in the Romagna, but he fell ill during the campaign and died in 1511, in Correggio.

Charles was considered a generous art patron in Milan, and in 1506, he asked the Republic of **Florence** if Leonardo could return to Milan for three months to complete some work for him. Leonardo ended up staying in Milan to work as an architectural advisor to Charles II and King Louis XII of France, which initiated his Second Milanese Period, and he abandoned his ***Battle of Anghiari*** wall mural in the Palazzo Vecchio in Florence, which had already suffered from mold and dripping paint. While in Milan, he made plans for a palace

for Charles and an oratory for the Church of Santa Maria alla Fontana, and he also continued work on his previous project to link Milan to Lake Como by rerouting part of the Adda River. None of his projects were realized during this time, but Leonardo did continue his scientific studies and annotated his **notebooks** for eventual publication. *See also* ARCHITECTURE; CLOS LUCÉ; *CODEX TRIVULZIANUS*; SCULPTURE, WATER STUDIES.

ANAMORPHOSIS. Leonardo's optical studies allowed him to better understand the visual paradox of **perspective** illusions, including anamorphic illusions, which are distorted images that can only be seen correctly through either a sharply angled viewpoint, called an oblique anamorphosis, or with a device like a mirror, called a catoptric anamorphosis. The word is Greek, and "ana" means "again," while "morphe" means "shape." Artists of the 1400s had already used isotropic scaling from Euclidean **geometry** to devise a pictorial presentation of three-dimensional objects whereby their original measurements could be preserved, so these artists were already familiar with affine transformations. Thus, the oblique, or perspectival anamorphoses, appeared first, while the more sophisticated mirror anamorphoses appeared later in the **Renaissance**.

Leonardo's drawing of an eye, seen at an oblique angle, is considered the first example of an anamorphic drawing. Done in about 1485, this sketch appears in his ***Codex Atlanticus***, fol. 98r, and since this codex is a miscellaneous collection of notebook pages, the context for this drawing is not fully known outside of Leonardo's general scientific interests. Here we see two eyes, with the one on the viewer's right stretched slightly, yet still easy to recognize, while the left eye is enlarged and stretched further so as to be unrecognizable until the viewer holds the paper at a 45-degree angle. This type of study reveals how perspective can shift dramatically with variations in the viewer's vantage point, thus showing the illusory nature of pictorial representations of objects, while also highlighting the connection between the body and the viewpoint. *See also* LINEAR PERSPECTIVE; MATHEMATICS; OPTICS.

ANATOMY. Renaissance artists sought to depict objects based on a careful observation of nature, and through the 1400s painters began a systematic study of animal and human anatomy that allowed them to heighten the level of realism in their art. Both Leonardo's teacher, **Andrea del Verrocchio**, and Verrocchio's Florentine contemporary, **Antonio del Pollaiuolo**, were interested in anatomy, and **Giorgio Vasari** noted that Pollaiuolo was the first artist to dissect human corpses. This interest in the human form dates back to antiquity, and Florentine humanist scholar **Leon Battista Alberti** wrote in his treatise *On Painting*, from 1435, that painters should depict human figures as they appear in nature. Leonardo grappled with this idea throughout his life, where he consulted such classical sources as **Vitruvius**, together with the work of contemporary artists.

One of the first artists to perform dissections in Italy after the fall of the Roman Empire was physician Mondino de' Luzzi (c. 1270–1326), a professor at the University of Bologna who wrote the earliest Italian treatise on human cadavers, called *Anathomia corporis humani*, in 1316, and he taught his students via public dissections after the prohibition against them was lifted by the Church. Luzzi's descriptions are detailed but not always accurate, and his references to ancient models like those by Aristotle and Galen limited his scientific advances. Both Leonardo and **Andreas Vesalius**, who studied in **Venice** and Padua, certainly knew this widely reproduced manual, but during the **Renaissance** scientists were beginning to realize that the use of such classical texts as Galen were not enough to fully understand the discipline. This idea is consistent with Leonardo's views that classical sources must be verified through careful observation.

Leonardo's earliest dissections date to the mid-1480s and were of horses, oxen, and birds, some of which were likely done while he worked in Verrocchio's studio and through his early years in **Florence**. He also sought to extrapolate an understanding of human musculature and tendons from his observations of figures in motion, similar to Pollaiuolo's observations in his *Battle of the Ten*

Nudes engraving from before 1470. Some of Leonardo's sketches demonstrate poses and gestures that originated in the **paintings** and **drawings** of both Verrocchio and Pollaiuolo, and these sources were a springboard for Leonardo's many drawings made directly from nature, which allowed him to deduce a firmer understanding of the human body through its careful observation. Leonardo intended to write a treatise called "On the Human Body," which never materialized. Instead, although Leonardo's drawings were not published until centuries later, they were widely available in the early 1500s and influenced many artists, one of whom was Northern European artist **Albrecht Dürer**, whose copies of Leonardo's lost sketches can be found in his *Dresden Sketchbook*, fols. 130v–131r. Dürer's treatise on human proportions was published in 1528.

Leonardo's first known study done from a human body dates to 1489, when he received a human skull in **Milan** and made a careful, annotated drawing with separate sketches of the teeth (Royal Collection, London). Milan was a center for medical advances, and through the 1490s, Leonardo made an outline for a treatise on human anatomy and **physiology** based in part on the medical traditions established by Galen and in part on Leonardo's own careful observations. By 1513, he had dissected approximately 30 human corpses and made more than 750 anatomical drawings, mainly of the human body. Many artists considered dissections too inhumane, and indeed, Leonardo noted you must have the stomach for such work. During this time, corpses could only be preserved temporarily on ice; therefore, most dissections took place during the winter months.

Leonardo listed in his **notebooks** that he used a bone saw, forceps, a scalpel, and a surgical knife for his studies. He made drawings of a few of his tools, one of which was a knife with a hooked blade. Most of Leonardo's anatomical drawings were begun in Milan in a notebook titled "On the Human Figure," dated 2 April 1489, which is now called the "Anatomical Manuscript B" (Royal Library, ***Windsor Folios***), and include a later series of pen and ink drawings of an elderly man Leonardo dissected during the winter of 1507–1508 in the Hospital of Santo Spirito in Florence. A second notebook, called "Anatomical Manuscript A" (Royal Library, *Windsor Folios*), includes approximately 240 more anatomical drawings and a related text.

Leonardo continued his anatomy studies in Florence in 1500–1506, where he had access to cadavers at the Hospital of Santa Maria Nuova, and during this second stay in Florence he maintained a studio at the Hospital of Santa Spirito, where his later anatomical studies focused on the heart, brain, and other organs. Leonardo noted that these highly realistic drawings, which gave the viewer a glimpse into the human body, were superior to a textual or oral description. Leonardo then initiated a third phase of anatomical study when he returned to Milan in 1506, where he began to work with physician **Marcantonio della Torre**, a professor at the University of Padua and the University of Pavia. During this time, Leonardo began to focus more on the movement of the body and made sketches of arms and legs swinging in a circular motion. His studies of human bones and tendons also imply movement through their musculature, as seen in numerous studies of the shoulder and arm now in the Royal Collection of the United Kingdom.

Leonardo noticed that blood flows like water in a river but is more viscous. Yet, despite a lifetime of anatomical study, he failed to fully understand the circulatory system. Leonardo did nonetheless make numerous medical discoveries. He made the first systematic examination of the human spine and wrote the first description of cirrhosis of the liver and arteriosclerosis. Leonardo's studies of the heart show that hearts have four chambers, not two, as was previously thought, and he also examined the pumping chambers, or ventricles, in movement. Leonardo's superior drawing ability allowed him to depict the heart in three dimensions and show its rotational movement, which he observed during the slaughter of several pigs for roasting. While examining an ox heart, found in a pen and ink drawing on blue paper from 1513, and now in the Royal Library at Windsor, Leonardo observed the movement of the aortic valve, which ensures an even flow of blood. Leonardo's two famous studies of a *Human Fetus in a Womb*, both approximately 12 x 8.5 inches,

from c. 1510, and now in the Royal Library at Windsor, are annotated with his observations made during the dissection of a uterus. Here Leonardo showed the correct breech placement of the fetus in the womb chamber, as well as the correct vascular system.

During Leonardo's lifetime, his innovations were informed by a dramatic expansion of human knowledge as physicians and artists both began to study anatomy through dissections. Leonardo's work was enormously influential to artists and scientists because of his highly realistic style, where he was able to render objects in correct proportion and **perspective**, which allowed him to depict the movement of the three-dimensional form with a high degree of accuracy. Leonardo planned to publish his treatise on anatomy, an idea confirmed by mathematician **Luca Pacioli**, who noted in his treatise on **geometry** that Leonardo had completed his treatise in 1498. While Flemish physician Andreas Vesalius's *On the Fabric of the Human Body*, published in 1543, is the first modern comprehensive study of anatomy, it was certainly informed by Leonardo's ideas on the primacy of dissection over ancient philosophical ideas on medicine. *See also* ANIMAL STUDIES; CLASSICISM; SCULPTURE; *VITRUVIAN MAN*; VITRUVIUS, MARCUS POLLIO.

Leonardo da Vinci, *Human Fetus in a Womb*, c. 1510, 12 x 8.5 inches, ink on parchment, London, Royal Library, Windsor Castle

ANCHIANO. *See* VINCI.

ANEMOMETER. The first description of a mechanical anemometer, an instrument used to measure the speed of wind, was made by **Leon Battista Alberti** in 1450. Many different versions were built through the 1600s–1800s, but Alberti's version was fundamental to later concepts and consisted of a disk set perpendicular to the wind and attached to a rotating base so that the speed of rotation could be measured, as well as the angle of the disk. In the 1480s, Leonardo made several variations on Alberti's designs to measure the speed and direction of the wind in conjunction with his study of flight. Leonardo's drawing is found in the ***Codex Atlanticus***, fol. 675, and shows a piece of wood hanging in the center of a measured arch. When the wood is hit by the wind, it rises up to align with a particular measurement on the arch. Next to his drawing he wrote, "For measuring distance traversed per hour with the force of the wind. Here a **clock** for showing time is required." This is one of many practical designs Leonardo sketched to see if variations on existing technology could provide more accurate results with greater efficiency. *See also* AERODYNAMICS; *CODEX ON THE FLIGHT OF BIRDS*, ENGINEERING; FLYING MACHINES; INVENTIONS.

ANIMAL STUDIES. Leonardo made sketches of animals, both living and dead, real and imaginary, throughout his life. These animal **drawings** were done as both preliminary studies for his **paintings** and as scientific studies of movement and form for his eventual treatises on painting and **anatomy**. Either way, his sketches were characterized by a highly realistic depiction of the animal and its movement shown in such a way as to capture the character and energy of the animal; therefore, Leonardo not only studied the anatomy and movement of animals in a method similar to his **botanical studies**, but also sought to show their inner character.

For example, his full-page drawing *Cats, Lions, and a Dragon*, which is a pen, ink, and wash over black chalk drawing in the Royal Collection, London (RCIN 912363), shows more than 20 small drawings that cover the entire page of cats and lions seated, standing, sleeping, licking, awake, facing front, and facing away from the viewer, creeping and playing alone or in pairs. Clearly, Leonardo was exploring the similarities between these two feline types, while at the same time showing the more muscular and agile movement of the wild animal versus the repose of the domesticated cat. In the midst of these drawings is a dragon, shown twisting and turning like the lion, but with a long neck imagined from a variety of reptile creatures. Here we see how Leonardo studied visually accessible animals, and from them he theorized their wild counterparts not native to Italy. From this, he extrapolated imaginary creatures from known animals. In this way, Leonardo's scientific studies could be used as a bridge between the known world and the unknown.

Leonardo's earliest dissections were of horses, oxen, birds, and a bear, while most of his animal studies focused on horses since they appeared in several of his paintings, including his ***Battle of Anghiari***, where he studied the rearing horse with its head in three different positions and its front legs in two different positions (c. 1503, red chalk and pen and ink on paper, Royal Collection Trust, United Kingdom, RCIN 912336). Other drawings, for example, a proportional study of a horse with his back legs in several different positions (c. 1490, silverpoint on paper, Royal Collections Trust, United Kingdom), were done in preparation for several unfinished equestrian monuments, including the Gran Cavallo, a colossal horse and rider commissioned by **Lodovico Sforza** in 1482, to commemorate his father Francesco. Although never completed, Leonardo made extensive drawings of the horse and its armature needed to support the clay model, which was to be cast in bronze. Leonardo's animal studies were therefore both theoretical and practical, while his dissections allowed for both scientific and artistic interests. Many **Renaissance** artists studied animals, but the only other artist with a similar scientific approach to animal studies as Leonardo was **Albrecht Dürer**. *See also* NOTEBOOKS; PHYSIOLOGY; SCULPTURE, *WINDSOR FOLIOS*.

ANNUNCIATION. Leonardo's *Annunciation* is his earliest surviving painting and dates between 1472–1476. It is done in **oil** and **tempera** on poplar panel, measures 38.5 x 85.5 inches, and is located in the Uffizi Gallery in **Florence.** This work was originally attributed to **Andrea del Verrocchio** but is now universally recognized as by Leonardo, although many scholars consider it a collaborative work. Either way, it clearly reflects Verrocchio's stylistic influence on Leonardo's early panels

Here we see a depiction of the Annunciation from Luke 1, verses 26–39, where the Angel Gabriel kneels before the Virgin Mary and holds up his hand in a blessing as he begins to tell her that she will give birth to Christ. The Virgin appears on the portico of her stone house, seated in front of a lectern placed on top of a stone table that resembles a classical sarcophagus. She marks a passage in the devotional prayer book she has been reading with an elegantly posed right hand, while her left hand rises up in a slight gesture of surprise that acknowledges Gabriel. This Virgin has golden blond hair in the Flemish style that curls around her face and hangs down her shoulders, while her blue robe folds to reveal a yellow underside that covers a red belted tunic. Gabriel's rich robes fall onto a meadow of small white, blue, and pink flowers, while his wings remain alight, as if he just arrived a moment ago. He casts a shadow upon the ground, which reveals Leonardo's early interest in shading and shadowing. Gabriel looks across the white lilies in his hand, and his eyes lock onto the eyes of the Virgin, who seems to intuitively know the reason for his special visit. The white table, in the shape of a sarcophagus, alludes to Christ's early death, while the Virgin's stiff yet calm demeanor suggests her acceptance of this important yet sad responsibility. Beyond the retaining wall of the Virgin's garden is a landscape of carefully tended Cyprus trees, while farther back is Nazareth, a coastal city on the Sea of Galilee set against jagged mountains that rise up sharply in the distance and blend into the white clouds and sky. Scientific studies of the underpainting reveal numerous adjustments to its composition, typical of the early work of an artist who is painting this subject for the first time. Several **drawings** are related to the painting, including a sketch of the angel in reverse (**Rome**, Gabinetto Nazionale delle Stampe, Fondo Corsini 125770), a drapery study (Louvre drawing 2255), a study of the lilies (Royal Library, Windsor, inv. 12418), and a drawing of the angel's arm (Oxford, Christ Church College).

This painting was important in the establishment of Leonardo's oeuvre during the later 1800s, when scholars first attempted to clarify Leonardo's style and establish his corpus. The

Leonardo da Vinci, *Annunciation*, c. 1475, oil and tempera on poplar panel, 38 5 x 85.4 inches, Florence, Uffizi Gallery.

panel was first identified by **Karl Eduard von Liphart** in 1869, based on the connoisseurship of fellow German art historian **Gustav Friedrich Waagen**, who also worked in Florence during these years. The painting had just arrived at the Uffizi Museum from the Monastery of San Bartolomeo outside Florence and was first attributed to **Domenico Ghirlandaio**, an artist contemporary to Leonardo who was also trained in the workshop of Verrocchio. This early history of connoisseurship in art history highlights the difficulties of reconstructing an artist's career when many painters collaborated on work and shared a similar stylistic training. Ultimately, this painting reveals not only Leonardo's early training in the shop of Verrocchio, but also his emerging interest in **landscape** views and realistic figures tempered with a classical idealism. *See also* CATHOLICISM; CLASSICISM, PAINTINGS.

ANONIMO GADDIANO. Anonimo Gaddiano is the name given an anonymous Florentine author of the *Codex Magliabechiano*, a 128-page incomplete manuscript from c. 1537–1542 now located in the Biblioteca Nazionale Centrale di Firenze that predates **Giorgio Vasari** in its compilation of artist biographies. Although the author's name remains unknown, he was clearly someone who worked for the **Medici** family, while the manuscript was named after a Gaddi family owner and then after Antonio Magliabechi (1633–1714), the librarian of Cosimo III de' Medici, whose personal collection later formed the core of the Central Library of **Florence**. Forgotten after Leonardo's death, the manuscript was rediscovered in the 1890s, when Hungarian historian Cornelius von Fabriczy (1839–1910) published several articles in the *Archivio Storico Italiano* on this manuscript and another one by Antonio Billi from c. 1518 that provided a briefer account expanded upon by the Anonimo Gaddiano. In 1892, art historian **Karl Otto Frey** published the first edition of the *Magliabechiano*.

The text begins with an overview of ancient Greek artists, perhaps influenced by **Lorenzo Ghiberti's** *Commentaries*, and then focuses on Florentine artists from Cimabue through **Michelangelo**, and therefore covers the same scope of material as Vasari's text, which was compiled during this same time; however, while Vasari included anecdotal stories to reveal the personality of the artist, the *Magliabechiano* focuses more on listing works of art. Leonardo scholars frequently cite this document because the entry on Leonardo is one of the most detailed in the manuscript and provides numerous clues about Leonardo's extant work, including the possible identities of several of Leonardo's **portraits**, notably the ***Mona Lisa***. *See also ADAM AND EVE*; GIOVIO, PAOLO; MUSIC; PAINTINGS; SAN BERNARDO ALTARPIECE.

ANTONELLO DA MESSINA (c. 1430–1479). **Giorgio Vasari** credited Italian painter Antonello da Messina with the introduction of **oil** paint into Italy. Although this is perhaps factually incorrect, Antonello nonetheless popularized this new medium throughout the peninsula and laid the foundation for its exclusive use by many painters of the 1500s. Oil paint first became prevalent in Flanders in the early 1400s, and was best known in the panels of Jan van Eyck (c. 1390–1441), a painter who worked primarily in Bruges. As a court artist for Duke Philip the Good of Burgundy, van Eyck was sent on diplomatic visits throughout Spain and Portugal, and in this way, he introduced his innovative techniques with oil paint throughout Southern Europe and became known to Italian artists and humanists. In about 1450, Antonello was mentioned as studying in Naples with local painter Niccolò Antonio Colantonio, who painted in a Netherlandish style influenced by van Eyck. Both René of Anjou and his successor, Alfonso V, king of Aragon, Naples, and Sicily, established international courts in Naples and brought French, Flemish, and Spanish cultural influences to the region. Van Eyck's *Lomellini Tryptych* was in the Royal Collection in Naples during that time, as were numerous other Netherlandish paintings.

Antonello's *Saint Jerome in His Study* from c. 1474 (National Gallery, London) was done while he was in **Venice**, which is where Leonardo could have been introduced to his work. Alternatively, Leonardo could have

encountered Antonello's work in **Milan**, where Antonello perhaps went to work with van Eyck's follower, Petrus Christus (c. 1410–c. 1475), whose works were popular in Italy. Here we see a large interior space where Jerome is seated in the center in profile at a desk that is raised on a platform above the tiled floor. Built-in book shelves surround him and are filled with an assortment of containers and books. The room opens up on either side of the platform desk with halls that lead the viewer's eye back through two corridors to windows in the background. The painting is arranged such that the viewer sees Jerome through a stone doorway, where a peacock casts a shadow on the stoop. This is perhaps one of the first works in Italy to not only show such a high level of detail characteristic of Netherlandish painting, but also Antonello has expertly captured an atmospheric quality to the room, where soft, diffuse lighting and shadows reveal a space that seems tactile even in its voids. It is this idea of filling the space between objects that interested Leonardo, who invented his **sfumato** technique to suggest a similar haziness.

Antonello's **portraits** also follow a Netherlandish model, where the half-length figure appears in a three-quarter view set against a dark background. His *Virgin Annunciate* from c. 1476 (oil on wood, Palermo, Palazzo Abatellis) shows this format. Here the Virgin is interrupted in her reading by the Angel Gabriel, who does not appear in the painting but stands outside in the space of the viewer. She reaches her hand out so that we can see her palm facing downward, a gesture Leonardo adopted in his ***Virgin of the Rocks***. Leonardo also adopted the same dark monochrome background, seen in his ***Lady with an Ermine***. Antonello da Messina's style was enormously influential throughout Italy during the **Renaissance**, yet he never received the level of acclaim enjoyed by such artists as **Raphael**, Leonardo, and **Michelangelo**. Although he was mentioned by Vasari, it was perhaps the fact that he never worked in **Florence** that kept him from achieving the same degree of fame as these three artists. *See also* ATMOSPHERIC PERSPECTIVE; BELLINI, GIOVANNI; CATHOLICISM, LIGHT.

ANTONIO DE BEATIS. *See* CLOS LUCÉ; *SAINT JOHN THE BAPTIST.*

ARCHITECTURE. Leonardo was frequently hired as a structural advisor on various architectural projects, although he was never responsible for any building. In addition to his practical solutions for the dome of the Cathedral of **Milan** and his various fortification designs and canal projects, he also theorized ideal church plans and cities. He made numerous architectural **drawings** throughout his career, which were first gathered together in the 20th century by **Jean Paul Richter**, who devised a thematic organization of Leonardo's **notebooks**. His architectural studies ranged from sketches of the tools needed for construction, measurements of a building's support system, new types of fortifications and instruments of warfare, and different types of ground plans.

It is thought that Leonardo worked with **Donato Bramante** and Ambrogio de' Cortis in the 1490s on renovations to the Piazza Ducale and Sforza castle in Vigevano, located west of Milan. **Lodovico Sforza** was born in the Castello Sforzesco in Vigevano, and the Sforza family established the town as a bishop's seat, so Leonardo's advisory work extended across Sforza territories throughout Lombardy. Leonardo is documented as having stayed at the Castello Sforzesco, where he could have studied how the older fortifications were attached to the newer, more elegant building via a raised road. The regularization of the Piazza Ducale in front of the Castello could also have inspired Leonardo in his later designs for an **ideal city** plan in Milan, while documents also show Leonardo submitted a model for the main tower of **Milan Cathedral** that was never executed. Nonetheless, his encounter with mathematician **Luca Pacioli** in Milan inspired his interest in architectural proportional systems, and later in his life, Leonardo theorized an ideal city plan for **Romorantin**, a medieval town in the Loire Valley along the Sauldre River in north-central France near the royal châteaux of Blois and Chambord. Several drawings located in the British Library in London (primarily fols. 270–71) date to 1517, and show this plan, done for King **Francis I**.

Carlo Pedretti was the first scholar to study Leonardo's proportional studies in architecture, found in a **perspective** sketch of a church from c. 1515 (Accademia, **Venice**, fol. 238v). Jean Guillaume then made the first systematic study of Leonardo's architectural drawings, focusing on Leonardo's ground plan and exterior view of a centrally planned church (***Codex Ashburnham*** 2037, fol. 5v, and ***Paris Manuscript B***, fol. 95v), which Guillaume attempted to recreate in a small model exhibited in Montreal in 1987. In this case, Leonardo appeared to be working out a centrally planned church at a time when, although it was considered an ideal solution, was far less common than the longitudinal church that could house more people. *Manuscript B* has about 80 architectural drawings with plans, elevations, and architectural details mainly on the folded pages of fols. 1, 2, 3, 4, 6, and 10, the majority of which focus on a study of the central plan (72 drawings), with eight basilica-plan churches represented. Leonardo's best-known architectural study was a plan for an ideal city made for Lodovico Sforza, Duke of Milan, while studies of temporary architecture are found on fol. 719r of the ***Codex Atlanticus***, focusing on dome centering and scaffolds for Milan Cathedral.

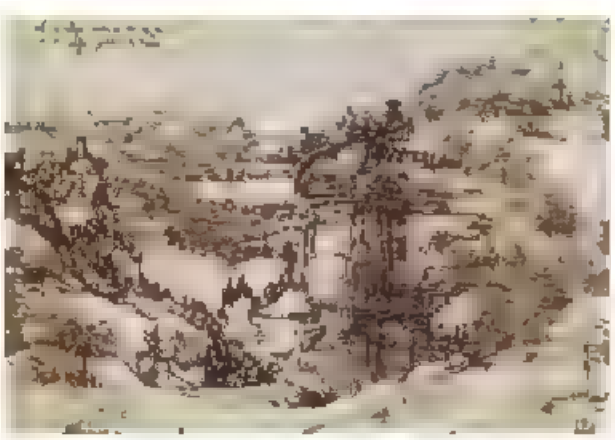
Leonardo was also hired as a military architect for **Cesare Borgia** between 1502–1503, and during this time, he built a canal from Cesena to the Porto Cesenatico, designed fortification expansions, and drew the earliest known ichnographic map as an aerial view of the town of Imola. Leonardo's architectural work, therefore, was part of his **engineering** interests, while his artistic interests could be found in his theoretical plans. *See also* ALBERTI, LEON BATTISTA; CARTOGRAPHY; FILARETE, ANTONIO DI PIETRO AVERLINO; MARTINI, FRANCESCO DI GIORGIO; VITRUVIUS, MARCUS POLLIO.

ARISTOTLE. *See* ANATOMY; BIOMECHANICS; BOTANICAL STUDIES; CHEMISTRY; *CHRIST CARRYING THE CROSS*; COLOR; DIVING SUIT; FICINO, MARSILIO; HUMANISM, LATIN; NOTEBOOKS; PHYSIOLOGY.

ARMORED CAR. *See* INVENTIONS; TANK.

ARNO VALLEY LANDSCAPE. Leonardo's first **landscape** was a view of the Arno Valley done in pen and ink on parchment that dates 5 August 1473, and measures 7.5 x 11.2 inches (**Florence**, Uffizi Gallery). It is Leonardo's first dated work and was drawn while he worked in the shop of **Andrea del Verrocchio.** This beautiful sketch shows a view from the Apennines, where Leonardo traveled regularly and worked on the development of mathematical **perspective** needed to depict depth in his **paintings**. In this drawing the cultivated land reveals a loose grid pattern, used to create orthogonal lines back to the viewer's left, where the land stretches out into the distance. The view shows Montelupo Castle on the viewer's left with a notation that the drawing was made for Santa Maria delle Neve, which is likely the church in Montaghari near Greve, where the noble Gherardini family owned a castle and farmland south of Florence. Leonardo would have been standing at the top of the mountain looking down and out across the land. The angle of his view, calculated at about 45 degrees, shows the undulating lines of the mountain opening up to reveal striated rock patterns that lead the viewer's eye down the gorge to the valley below.

This landscape is the first "pure" landscape, or view of the land without human figures. Nonetheless, these pure landscapes still often showed human intervention through the



Leonardo da Vinci, *Arno Valley Landscape*, August 5, 1473, pen and ink on paper, 7.5 x 11.2 inches, Florence, Uffizi Gallery.

appearance of paths, cultivated fields, and architecture, which raises questions about the narrative meaning of such a new subject. While Leonardo's **drawings** are clearly scientific studies, once the pure landscape became the subject of a painting, its narrative was transferred to the land itself. This new genre, widely popular during the next several centuries, was anticipated by Leonardo in his early landscape views such as this one. *See also* ATMOSPHERIC PERSPECTIVE; CARTOGRAPHY; GEOLOGY, LINEAR PERSPECTIVE.

ASTROLOGY. *See* ASTRONOMY.

ASTRONOMY. Astronomy and astrology shared many traits in the **Renaissance**, and astrological ideas were widely promoted by such humanist scholars as **Marsilio Ficino** in **Florence**. While astrology was based on ancient Greek ideas, primarily from Ptolemy, by the 1400s it also included advances made throughout the Middle Ages by Islamic scholars, whose writings had been introduced in Italy beginning in the 1200s. In the Renaissance, it was common for members of the nobility to commission natal charts at a child's birth and consult astrologers when making both personal and political decisions. Ptolemaic astrology gained ground in the Renaissance revival of antiquity, but a new scientific mindset led the charge to rationalize astrology. Astrology and astronomy are often used interchangeably to describe the celestial studies of this era. Astronomical studies, however, were focused on discovering and measuring the solar system following scientific practice, which led to revolutionary ideas about how people viewed the universe. These measurements were particularly important for sea travel, where ships could be guided by calculating their position in the ocean relative to the location and distance of star patterns and the sun.

As a **polymath**, Leonardo's interest in astronomy was one small part of his larger scientific and mathematical interests. Yet, his careful observations of the moon led to his important discovery of earthshine. Earthshine is the **light** source that illuminates the rest of the moon when the crescent shines from the light of the sun. Leonardo hypothesized the idea of earthshine while seeking to depict the moon realistically through artistically rendered shading and shadowing. An image of the moon appears in the ***Codex Leicester***, with the heading, "Of the Moon, No Solid Body Is Lighter than Air." Leonardo then went on to describe the moon as covered with water and suggested that water reflects light that bounces off the earth's oceans from the sun and that the moon is not luminous but must reflect light. **Nicolaus Copernicus s** theories on the sun-centered solar system were published in 1543, but the telescope was not invented until the early 1600s, so while Leonardo incorrectly assumed water was needed on both surfaces to reflect light, which led to his assumption that water must have covered the moon's surface and that the earth's water reflects light, we now know clouds are the primary source of reflection.

Through Leonardo's optical studies, he was able to intuit many things about the physical world, together with his studies of ancient texts. He owned a copy of Ptolemy's *Cosmography*, as well as a copy of medieval Persian astronomer Abu Mashar's astrological treatise. Thus, while most scholars remained committed to Aristotelian thought during the Renaissance, Leonardo's studies anticipated the ideas of **Galileo Galilei**. *See also* CARTOGRAPHY; CLASSICISM, MATHEMATICS; OPTICS.

ATMOSPHERIC PERSPECTIVE. This term, also called aerial **perspective**, is a technique used to suggest depth in a painting. The artist will use less saturated colors for the background objects so they blend into the **color** of the sky, while lines and colors gradually decrease in detail and contrast to give the appearance of great distance. Atmospheric perspective first appeared in antiquity, and it is well known today in the *Garden Scene* wall mural from the House of Livia, c. 30 BCE, in Prima Porta, Italy. This technique reappeared in the early 1400s, in **Masaccio's** *Tribute Money* **fresco** in the Brancacci Chapel in Santa Maria del Carmine, **Florence**, from the 1420s.

Many artists experimented with atmospheric perspective through the 1400s, while

Leonardo was the first artist to specifically define the technique in his ***Treatise on Painting***, where he observed that colors become weaker in proportion to their distance from the person who is looking at them. Leonardo's description anticipated modern scientific studies, where the visual phenomenon of distance is explained as a scattering of **light** as moisture and particles in the air cause light to disperse in different directions. Since blue has the shortest wavelength of the **Renaissance** color palette, backgrounds tend to appear a light gray-blue in Leonardo's **paintings**. Meanwhile, distant objects appear smaller, less detailed, and lighter in color than foreground objects. Leonardo's later paintings, for example, his ***Mona Lisa***, show both atmospheric perspective and **sfumato**, where a hazy impression gives a tactile quality to the space between objects and their distance from the viewer. *See also* CARTOGRAPHY, CLASSICISM; LINEAR PERSPECTIVE, PERSPECTIVE.

ATTITUDE INDICATOR. *See* FLYING MACHINES.

AUTOMATON. One of Leonardo's best-known **inventions** was his robotic knight, sometimes called his mechanical knight or Leonardo's robot. Leonardo was fascinated with human **anatomy** and its movement, and his work in both mechanical and civil **engineering** provided him with the technical background to create a variety of machines that moved with gears, levers, and pulley systems. While many of these inventions were designed for a practical purpose of moving water in canals, digging earth for construction, or designing portable **bridges** for warfare, Leonardo was also employed by Duke **Lodovico Sforza** of **Milan** to design stage sets and entertainments for his many courtly festivities and performances. Leonardo's automaton, designed in about 1495, for one of these events, consisted of a human figure that moved via a mechanical system built inside of a knight's armor.

Drawings for various robotic concepts appear in his **Madrid Codices** and his ***Codex Atlanticus***, specifically fols. 579r, 1077r, 1021r, and v, although a sketch of the complete robot has not been found. Nonetheless, studies of these drawings confirm that the figure could sit, stand, and move its arms, operated with a pulley system and gears. The legs could move at the ankles, knees, and hips, while the arms were designed to move at the shoulders, elbows, wrists, and fingers in such a way that the joints could all move at once. The chest was embedded with the control system, while the legs moved with an external crank. Although it is not clear whether or not Leonardo ever built the robot, it was described as part of the courtly festivities in Milan in 1495, and the robot has been built since then and is fully functional. Leonardo's other automata include his mechanical lion (*Madrid Codices I*, fols. 90v and 91r) and **self-propelled cart**. *See also* BOATS; CANNONS; DIVING SUIT; PHYSIOLOGY; ROME; SCYTHED CHARIOT; 33-BARREL ORGAN; TANK; WHEEL-LOCK MUSKET.

B

BACCHUS. Leonardo made a sketch of *Bacchus*, perhaps for a painting he never completed during his Second Milanese Period. Today, a *Bacchus* painting located in the Louvre Museum is likely based on this lost drawing. The painting, originally a Saint John the Baptist, is an **oil**-on-walnut panel transferred to canvas (70 x 45 in.) that was completed by an unknown student in Leonardo's workshop, likely between 1506–1513. The painting depicts a seated male figure wearing a fur loincloth and crossing one leg over the other. His body turns away from the viewer while he looks directly out of the painting and points behind his right shoulder to something outside the painting. He is seated on a tree stump and surrounded by nature, with a ridge rising behind the viewer's right side as the left opens up to a distant landscape. The soft modeling and restricted brown **color** palette recall Leonardo's style. In the late 1600s, the figure of the Baptist was repainted as a *Bacchus*, which was considered more fitting to its appearance as a young, seminude man, while the Baptist's staff was transformed into a thyrsus with a vine wreath. Three known copies exist of this work in its original form as a figure of Saint John the Baptist, one of which was done by Leonardo's student, **Cesare da Sesto**. Like many of Leonardo's lost and incomplete works, we can discern something about their original format through these student copies. *See also* LANDSCAPES; LEONARDESCHI; MILAN, PAINTINGS.

BADIA FIORENTINA. This Benedictine church in **Florence** is the site of the da Vinci family tomb, where Leonardo's father Ser Piero was buried in 1504, as well as his three sisters in 1477, 1490, and 1505. The church is located on Via del Proconsolo in the oldest neighborhood in the city, and it is thought to be the church where Dante first saw Beatrice. Leonardo's father's first wife, Albiera (d. 1464), and her daughter, Antonia (d. 1463), were buried earlier in the church of San Biagio in Florence, while Leonardo died in France on 2 May 1519, and is buried in the Chapel of Saint-Hubert in Amboise, France. *See also* CLOS LUCÉ.

BANDINI BARONCELLI, BERNARDO DI (1420–1479). Bernardo Bandini was a Florentine merchant who orchestrated the Pazzi Conspiracy of 1478, when Giuliano de' **Medici** was murdered and Lorenzo de' Medici wounded inside the **Florence** Cathedral. Bandini then fled to Constantinople, where he had trade relations, but he was arrested there a year later by Mehmed II, the Ottoman sultan, at the request of the Medici family, who had important trade contacts in Constantinople. Bandini was brought back to Florence by a Florentine representative and hanged six days later in front of the Bargello. Leonardo witnessed the public hanging and made a famous sketch now located in the Musee Bonnat in Bayonne, France (1479, 7.5 x 2.8 in., pen and ink, inv. 659). In this sketch, Leonardo shows the man's body hanging down from the noose tied around his neck while his hands are tied behind his back and his feet hang free below his long robe. Leonardo did not describe the details of the body, likely because he was more interested in the mechanics of a body in motion.

Above the sketch Leonardo wrote a description of Bandini's exotic clothing, with his tan skullcap, black pants and hose, and blue coat lined with fox fur, which was an outfit from Constantinople, unlike the clothing worn in Florence. It was common for artists to sketch or paint the men hanged in front of the government buildings, and both **Andrea del Castagno** and **Sandro Botticelli** were hired to depict such traitors as a reminder to the citizens of Florence of the high price of betrayal. About 80 men were hanged in Florence after the Pazzi Conspiracy, while both Bandini and the merchant Napoleone Francese escaped, so it would have been a relatively common public image. When Bandini was hanged, it was requested he specifically be hanged in his foreign clothing, making him appear to be an infidel, as well as a traitor, and he was called a "new Judas" because the Medici murder took place inside the Florence Cathedral. While these public hangings and their painted effigies were specifically used to shape public opinion, Leonardo's rough sketch, which is an interesting representation of this historical event, was a study in the pose and clothing of Bandini. *See also* ANATOMY; DRAWINGS; PHYSIOLOGY, RENAISSANCE.

BAPTISM OF CHRIST. *See* VERROCCHIO, ANDREA DEL.

BATTLE OF ANGHIARI. The *Battle of Anghiari* is known today from several copies, including the best known and most complete example by Flemish Baroque painter Peter Paul Rubens (1577–1640), now in the Louvre Museum in Paris. Rubens's work dates to 1603, and is called *The Battle of the Standard.* In 1504, Leonardo received a commission to paint a battle scene on one wall of the Salone dei Cinquecento in the Palazzo Vecchio in **Florence**, while **Michelangelo** was to paint a similar battle scene on the opposite wall. This large audience chamber was not only the most important room in the government building, but also the largest government room in Italy during the **Renaissance**. Popular Dominican preacher Fra **Girolamo Savonarola** had the room built in 1494, after wresting control of Florence from the **Medici** family, who had just been sent into exile. Savonarola ruled the city until he was condemned as a heretic in 1498, and during this time he established a broad-based government of 500 council members, which met in the audience chamber. After his death, **Piero Soderini** was elected leader of the Republic of Florence and commissioned the wall murals, which remained incomplete when the Medici returned to power in 1512.

Leonardo began work on designs for a scene of the *Battle of Anghiari* while Michelangelo worked on the *Battle of Cascina.* Because the wall space was so large, Leonardo first built a newly designed folding scaffold. He also hoped to use **oil** paint similar to his ***Last Supper*** mural in **Milan.** This time, however, he created a thicker intonaco mixed with wax, but he soon discovered the pigments could not soak into the plaster, nor could they dry fast enough, so they dripped off. When Leonardo's new mural technique proved unsuccessful, he abandoned the work and returned to Milan, while Michelangelo also left his work incomplete when he was called to **Rome** to carve the tomb of Pope Julius II. Meanwhile, in 1512 painter Bartolommeo (Baccio) Bandinelli (1493–1560) destroyed Michelangelo's cartoon, which is also known today in preparatory **drawings** and an engraving. **Giorgio Vasari** then completed the wall murals after the Medici returned to the palace in 1540, and he covered up what might have been some of Leonardo's extant preliminary work.

The Battle of Anghiari was a historical event that took place in 1440, between Milan and the Italian League, led by Florence. The battle was a pivotal victory for Florence, ensuring their dominance over the region of Tuscany. The famous central scene, documented by Rubens, depicts four men in the midst of battle over the standard, which they all reach out to grab while clutching their swords and grimacing in fury. Documents explain that Leonardo first drew a cartoon and pinned it to the east wall of the church of Santa Mar a Novella. The cartoon featured Niccolò Piccinino, a mercenary soldier who worked for the Milanese, in the midst of a turbulent battle. Battle horses twine together in tension and trample several fa len

soldiers beneath their hooves. The exaggerated facial expressions of the soldiers reveal Leonardo's studies of **caricature**, which appear in many of his preparatory drawings and later copies. Rubens's version demonstrates subtle differences, leading scholars to assume it was likely done from an engraving by Lorenzo Zacchia dated 1553, rather than from Leonardo's original cartoon, which could have been destroyed by then. Today, scholars are exploring the possibility that some of Leonardo's work can be found beneath Vasari's frescoes with new camera and radar technology, and perhaps in the future parts of the mural can be recovered, despite controversy concerning the methods of exploration and analysis. *See also* ANATOMY ANIMAL STUDIES; FRESCO, MUSEUMS, PAINTINGS.

BELLA PRINCIPESSA. This painting on paper depicts a profile portrait of a young woman with reddish hair combed back and bound into a ponytail, and has been attributed by some scholars to Leonardo, during the time he worked for the Sforza in the 1490s. The portrait is painted with black, red, and white chalk and ink, measuring 10 x 9 inches on a sheet of vellum attached to an oak panel. In the profile view, clothing and hair are similar to the profile portrait of Beatrice Sforza done by Leonardo's student, **Giovanni Ambrogio de Predis**, during this same era, so the work is certainly consistent with Leonardo and his shop. It was first attributed to Leonardo by **Martin Kemp**, who wrote about the work in his book *La Bella Principessa: The Story of the New Masterpiece by Leonardo da Vinci* (2010). Most scholars, including **Carlo Pedretti**, agree with Kemp's assessment, which was formed through careful technical analysis of the pigments and paper, while other scholars consider the work an excellent forgery and argue that the image is too stiff and does not demonstrate Leonardo's characteristic depiction of an emotional connection between sitter and viewer.

The portrait first caught the attention of scholars in 1998, when it was sold to a private collector as a German work from the 19th century. Further research showed that the page was cut out of a leather-bound manuscript called the *Sforziad*, made in the court of **Lodovico Sforza** in **Milan** and is now in Warsaw, with exactly the same stitch holes in the binding. The book was rebound in the early 19th century, at which point the page could have been removed. The portrait then emerged in 1955, in the collection of Italian painter and art restorer Giannino Marchig (1888–1983), who sold the painting through Christie's in 1998. In 2009, a private patron who had purchased the work in 2007 commissioned highly detailed microscopic photographs from Lumière Technology in Paris, which appear to reveal a fingerprint attributed to Leonardo based on its match to a fingerprint on Leonardo's firmly attributed ***Saint Jerome in the Wilderness.*** The photographs also attest to left-hand hatching in this highly realistic work, and Leonardo was highly unusual in that he painted and wrote with his left hand. Furthermore, Leonardo was the first Italian artist to use black, red, and white chalk, introduced to him by French portrait painter Jean Perreal (c. 1450–1530), who Leonardo mentions in a notebook page in the ***Codex Atlanticus***, while in Milan.

Pedretti has suggested that the work could be a prospective bride painting, done to help a suitor select a bride from a short list of two or three eligible young women. This would explain the use of parchment, since the painting would need to be portable, and it would have had no value after the marriage was arranged. In this case, it would make sense for the work to depict Bianca Maria Sforza the niece of Lodovico Sforza, and the image could have been made for Emperor Maximillian, whom she married in 1494. Whoever the young girl is, her fashionable clothing demonstrates a connection to Lombard aristocracy. *See also BELLE FERRONNIÈRE*; DRAWINGS; *GINEVRA DE' BENCI*; *LADY WITH AN ERMINE*; *MONA LISA*; PAINTINGS; *PORTRAIT OF ISABELLA D'ESTE*, PORTRAITS.

BELLE FERRONNIÈRE. This portrait, also called *Portrait of an Unknown Woman*, is attributed to Leonardo and shows a young woman wearing a jeweled headband unique to Lombardy in the **Renaissance.** The hairpiece gained popularity in Europe in the early 1800s

and was called a ferronnière, which provided the French name for this painting, located in the Louvre Museum in Paris. The term was based on the erroneous notion that this portrait depicted the mistress of King **Francis I** of France, who was the daughter of an iron merchant. Throughout the years the woman in the painting has also been identified as Lucrezia Crivelli while more recent scholarship suggests that the woman could be Beatrice d'Este, the wife of Duke **Lodovico Sforza** of **Milan**. The painting dates to c. 1490–1496, and is an **oil**-on-wood panel, 24 x 17 inches in size. The painting was first attributed to **Bernardino de' Conti** by **Bernard Berenson**, while it has also been attributed to other Lombard students and followers of Leonardo, including **Giovanni Antonio Boltraffio**. It was widely copied, and a canvas version of the painting was the subject of a famous lawsuit and subsequent book written about the court case by Harry Hahn called *The Rape of La Belle* (Kansas City. Frank Glenn, 1946), a dramatic account of intrigue and art forgery.

In this painting, we see a beautiful young woman looking out toward the viewer with her face turned at a slight angle. Unlike the frontal image of the ***Mona Lisa***, this young woman turns her half-length torso in a three-quarter pose toward the viewer's left, while posing in front of a white stone ledge that separates her space from the space of the viewer. She wears a beautiful red dress with a square neckline trimmed in gold. Her red sleeves are tied onto the bodice of her dress with gold ribbons, while her white inner shirt billows out slightly at the seams. A necklace of ribbons twines around her neck several times, drawing our eyes to her porcelain white skin, which leads us to her face. Her hair is parted in the middle and tied back in a low ponytail, while the headpiece, with its delicate gold jewel, frames her forehead. This interesting piece of jewelry and hairstyle were both popular in Milan during this time and were very different from Florentine style, which gave Lombard women a unique identity. The background is a dark black, which is consistent with the work of several of Leonardo's students in Milan. The attribution to Leonardo, however, is based on the soft realism and mastery of oil paint, which allowed the artist to depict individual strands of golden brown hair, smooth skin revealed through subtle shading, and the limpid eyes so famously represented in Leonardo's *Mona Lisa* and his ***Lady with an Ermine***. Regardless of attribution, this work is one of the best portraits of the Renaissance in its artful technique of realism. *See also BELLA PRINCIPESSA*; *GINEVRA DE' BENCI*; PAINTINGS; *PORTRAIT OF ISABELLA D'ESTE*; PORTRAITS.

BELLINCIONI, BERNARDO (1452–1492). Bernardo Bellincioni was a Florentine court poet who first worked for Lorenzo de' **Medici**, then he moved to Mantua to work for the Gonzaga in 1483, and he finally settled in **Milan** in 1485, to work for **Lodovico Sforza**. There he wrote sonnets, eulogies, and other types of poems and allegories recited at court festivals and royal weddings, including a booklet of poems called *La Festa del Paradiso* that he wrote for the marriage ceremony of Gian Galeazzo Sforza and his 19-year old cousin Isabella of Aragon in 1488. The marriage was celebrated in 1490, when Bellincioni's poetic text was read aloud to musical accompaniment in front of a stage set designed by Leonardo. Bellincioni also wrote a sonnet for Cecilia Gallerani, depicted in Leonardo's famous ***Lady with an Ermine*** portrait, and described Leonardo's painting as revealing a woman who was the envy of nature and who seemed to listen but not talk, an ideal trait for aristocratic women in the **Renaissance**. *See also* FLORENCE; MUSIC; PAINTINGS, PORTRAITS.

BELLINI, GIOVANNI (c. 1430–1516). Giovanni Bellini is one of the best-known Venetian painters of the Italian **Renaissance** and an artist whose style is most similar to Leonardo's. His father and brother were both painters, and his brother-in-law was **Andrea Mantegna**, who was working for Isabella d'Este in **Mantua** during the three months that Leonardo was there as a guest of the Marchesa, an important art patron in northern Italian court circles. Leonardo would certainly have met Mantegna there, and after he left Mantua for **Venice**, he would most likely have had the opportunity to

meet Giovanni Bellini a month later. Bellin. is credited with popularizing **oil** paints in Venice, wh ch had been introduced in the city by **An tonello da Messina** in 1473, and this new medium al owed h m to create the rich **color** and subtly muted tones, which Leonardo also sought in his work. His works also display a haziness, or **sfumato**, which is Leonardo's best-known stylistic feature, and Bellini's later paintings show a golden light that makes the space between his figures and objects appear more tangible. Both artists then, are credited with devising this new atmospheric style at the same time.

While in Venice, Leonardo could have seen Bellini's *San Giobbe Altarpiece*, one of his earliest oil paintings, done in about 1487 (Venice, Gallerie dell'Accademia), for an altar at the Church of San Giobbe in Venice. This painting was perhaps inspired by Antonello's *San Cassiano Altarpiece*, which was one of the first large altarpieces painted in oil in Venice, in about 1475 (Vienna, Kunsthistorisches Museum), and it introduces a new monumentality and subtle gradations of color. Bellini's painting is a sacra conversazione organized in a triangular format, a compositional dev ce also favored by Leonardo. Here, however, the Virgin is enthroned and flanked by three saints on either side, whi e three music-making angels form a smaller triangle at the stoop of the throne. The interior space, rendered to echo a semicircular chapel with a mosaic apse lunette, is done in mathematical **perspective** and features flanking columns that match the ones outside the painting to show how space flows from the church interior into the painting

Venetian art was increasingly becoming famous outside the Veneto, in part due to the thriving humanist culture, prosperous trade, and important printing presses established there in the late 1400s. The humanist writings of Marcus Antonius Coccius Sabellicus (1436–1506), who was appointed curator of the Biblioteca Marciana in 1487, included a scholarly description of Venice called *De Urbe Sito*, which Leonardo could have discovered wh le in Venice, and **Giorgio Vasari** included Venetian artists in the second edition of his *Lives of the Most Excellent Painters, Sculptors, and Architects*, published in 1568, with woodcuts. *See also* HUMANISM; MATHEMATICS; PAINTINGS.

BENOIS MADONNA. The *Benois Madonna* is a small (19 5 x 13 in.) **oil-on-wood** (now transferred to canvas) painting attributed to Leonardo that depicts a seated Madonna with the Christ Child on her lap, laughing as both of them hold a small white flower. This early work is perhaps the first independent work of Leonardo, completed after he left **Andrea del Verrocchio's** studio in **Florence**, and it may well be one of the paintings Leonardo mentioned on a notebook page as having begun in October 1478. This painting, now in the Hermitage Museum in Saint Petersburg, has two related **drawings**, both of which are in the British Museum in London. Here we see a three-quarter portrait of the Virgin with a round, youthful face seated on a bench inside a room. She is dressed in a dark green and brown robe, while her lap is covered with a brown and blue drape. The chubby Christ sits on her lap and clutches the stem of the flower that the Virgin holds out to him. Thin golden haloes frame their heads, while the dark interior is punctuated on the back wall with a double window that opens to reveal a few subtle clouds in a light blue sky. This painting is considered to be from the same period as Leonardo's ***Madonna of the Carnation***, which features a more complex subject where the Virgin offers a single carnation to the squirming Christ Child, but in that case a rocky landscape appears out the paired background windows while the Virgin's face and drapery are in a different style

The *Benois Madonna* is named after Leon Benois, who sold the painting in 1914, to Tsar Nicholas II, for the Hermitage, and although most scholars consider the attribution correct, early art dealer **Bernard Berenson** did not think this work a good example of Leonardo's style. The Benois family had inherited the painting after it was brought to Saint Petersburg from Italy by Russian art connoisseur Aleksey Korsakov (1751–1821) in the 1790s. In his **notebooks**, Leonardo mentioned painting several Madonna and Child images during his early years in Florence, and indeed

this was a popular subject continued by **Raphael** in Florence after Leonardo left for **Milan**. A *Madonna of the Pinks*, c. 1506 (London, National Gallery), recently attributed to Raphael, was perhaps inspired by Leonardo's idea of the shared flower. *See also* CATHOLICISM; LANDSCAPES, PAINTINGS.

BERENSON, BERNARD (1865–1959). Bernard Berenson was an American art historian best known as a champion of Italian **Renaissance** art emerging in popularity in the United States in the early 1900s. Born into a modest immigrant family in Boston, Berenson studied at Harvard and traveled to **Florence**, where he met **Giovanni Morelli**, who was known for his unique method of connoisseurship, which involved identifying an artist by the small details and incidental parts of a painting, which Morelli argued were the subconscious markers of an artist's style. Berenson became a protégé of Morelli and introduced his method of connoisseurship in the United States. Many American collectors relied on Berenson's authentications in establishing some of their early collections of Italian Renaissance art held in **museums** today, including the Metropolitan Museum of Art in New York and the Isabella Stewart Gardner Museum in Boston. He worked with British art dealer Joseph Duveen, as well as Colnaghi in London and Wildenstein in New York City, to authenticate **paintings** sold in Europe and the United States.

Berenson became very wealthy from this work with art dealers and patrons, and lived at the Villa I Tatti outside Florence, which was donated to Harvard University upon his death. His book *The Italian Painters of the Renaissance* was first published in 1953, from a collection of his turn of the century art historical essays, and it shaped our understanding of Italian Renaissance art style today despite the fact that many scholars consider some of his attributions to be motivated by profit rather than academic value. Nonetheless, he confirmed **Karl Eduard von Liphart's** attribution of Leonardo's ***Annunciation***, among other paintings by Leonardo, and his work remains important in the history of the Leonardo connoisseurship. *See also BENOIS MADONNA*; BODE, WILHELM VON, FREY, KARL OTTO; MCCURDY, EDWARD ALEXANDER COLES; RICHTER, JEAN PAUL; WAAGEN, GUSTAV FRIEDRICH.

BILLI, ANTONIO. *See* ANONIMO GADDIANO.

BIOLOGY. *See* ANATOMY; PHYSIOLOGY.

BIOMECHANICS. Leonardo's interest in the natural world included the field of biomechanics, which in concept dates back to the ancient Greek notion of the mechanics of life, which focused on the movement of living organisms. Most of Leonardo's scientific observations were mechanical. While today biomechanics typically involves computer modeling and is related to **engineering** and other applied sciences, the discipline began with the ancient study of human and animal **anatomy**. Aristotle's *On the Movement of Animals* [Deo Motu Animalium], from the mid-300s BCE, is considered the first biomechanical treatise, written as part of Aristotle's broader observations on living creatures and his theories on motion. Anstotle's scientific studies were introduced in Western Europe in the later Middle Ages via Arabic works that, by the 1200s, had been translated into **Latin** and were widely known in the **Renaissance**.

Next, the ancient Greek medical scientist Galen of Pergamon, physician to Roman emperor Marcus Aurelius, wrote *On the Function of the Parts* in the 2nd century, which remained the standard text through the Renaissance, and although his theories were not always correct, his use of direct observation through dissections certainly influenced Leonardo's working method, and Galen's ideas were foundational in **Andreas Vesalius's** *De humani corporis fabrica*, published in 1543. Leonardo's anatomical studies were so realistic and his careful observations so accurate that, for example, his studies of the human foot and ankle structure and movement done, during his more than 30 dissections at the Santa Maria Nuova Hospital in **Florence** and Santo Spirito Hospital in **Rome**, are ultimately not much different from modern proportional studies of joint stability and foot support studies used for orthopedics

today. *See also* ANIMAL STUDIES; CLASSICISM; HUMANISM, PHYSIOLOGY.

BOATS. Leonardo designed many different types of ships and boats, some for warfare and others for quicker and more efficient movement through water. His paddle boat, found in the ***Codex Atlanticus***, fol. 945r, shows a paddle boat that is actually propelled by two pedals that move in a continuous turning motion with a belt and flywheel. While not original, Leonardo's design provides improvements to the engine mechanism, which turns the pedals more smoothly. This design was likely done in about 1487, while Leonardo worked in **Milan**. He also designed a 1,000-oar attack galley (***Paris Manuscript*** B, fol. 93r). This type of boat had 13 rows of oars on each side and a ram at the front of the boat that was covered by a shield. In this way, the rowers could ram into an enemy ship, reverse oars to row backward, and prepare to ram the ship again in a short amount of time, operating much like a medieval battering ram. In the same codex we find designs for an Escorpio boat (fol. 5v), inspired by a scorpion. This boat had a large, hooked scythe mounted in the middle of the boat that moved when a large weight it was attached to was thrown into the water. The scythe could rotate 360 degrees and was mounted on a platform in the center of a small boat powered with oars that could move and change direction quickly. It did not have sails, which would have hindered the movement of the scythe in battle.

Leonardo studied both ancient weapons and ships, as well as the attack patterns of animals, including insects. Leonardo's large scythe ship, found in sketches in the same notebook (fol. 9v), is a large warship mounted either vertically or horizontally with a giant scythe that could cut through the masts of an enemy ship. Finally, Leonardo also designed a destroyer ship, found in the same codex (fol. 90v), which has a hidden underwater machine that can ram the hull of an enemy ship. The ram, which Leonardo suggests could be a sharpened tree trunk, is moved with a pulley system directed by soldiers on the ship. Chains could be connected to the enemy ship to keep it in place while it was being rammed but could be quickly released when the ship started to sink. Leonardo also devised a variety of **cannons** used on ships in warfare, in addition to a multicannon gunship (*Codex Atlanticus*, fol. 1r), as well as a mechanical **submarine** (fol. 881r). *See also* AUTOMATON; BRIDGES; DIVING SUIT; ENGINEERING, INVENTIONS; SCYTHED CHARIOT, 33-BARREL ORGAN; TANK; WHEEL-LOCK MUSKET.

BOBBIN WINDER. One of Leonardo's many **inventions** was a crankshaft designed to turn thread on a bobbin, found in a drawing in the ***Madrid Codices*** I, fol. 29v. Here we see a drawing of the tool at the top of the sheet, two detail views below, and a written explanation between the sketches. This drawing pattern was typical of Leonardo, who would often provide an overview design at the top of the page, then a few details or different views below, together with an explanation written in neat paragraphs between the sketches. The crankshaft rotates the bobbin while the connecting rod moves the bobbin back and forth so the thread winds around the bobbin in even rows. While many of Leonardo's inventions were too impractical or lost until many years after his death, the automatic bobbin winder was put to use during his lifetime. *See also* DRAWINGS; ENGINEERING, NOTEBOOKS.

BODE, WILHELM VON (1845–1929). Prominent German art historian Wilhelm von Bode established the Kaiser Friedrich Museum, now called the Bode Museum, in Berlin, where he helped to build an art collection to rival those in Munich and Dresden. After completing his doctorate in art history at the University of Leipzig, he traveled throughout Europe, becoming a specialist in Dutch painting and Italian **Renaissance** art, which resulted in a number of books, notably his *Italienischen Bronzestatuetten der Renaissance*, published in 1906, one of the earliest art historical studies on Italian Renaissance **sculpture**. His fame in this area of research was later tarnished with an erroneous attribution of a sculpted bust of Flora to Leonardo, made in his *Studien über Leonardo da Vinci* (1921), which was never

translated into English. Nonetheless, his attributions and interests influenced American art patrons J. P. Morgan and Henry Clay Frick, and shaped their public art collections in New York City.

While German art historian **Gustav Friedrich Waagen** carefully documented his studies of Italian Renaissance art in collections throughout Europe, other early scholars, for example, **Karl Eduard von Liphart**, did not publish much scholarly research but instead passed along his ideas to his student, von Bode, who is credited with writing the first cohesive overview of Leonardo's life and oeuvre. He focused on Leonardo's humble origins and work in the studio of **Andrea del Verrocchio** to solidify Leonardo's early career and added the ***Ginevra de' Benci*** to his oeuvre. Von Bode often disagreed with the attribution work of his contemporary rival, **Giovanni Morelli**, whose method of identifying an artist through incidental details did not suit von Bode's method of formal analysis. Morelli instead launched a persuasive argument that the *Ginevra de' Benci* portrait was by Verrocchio, while both von Bode and Morelli claimed to have been first to identify Leonardo's ***Annunciation***. *See also* BERENSON, BERNARD; FREY, KARL OTTO; MCCURDY, EDWARD ALEXANDER COLES, MUSEUMS, RICHTER, JEAN PAUL.

BOLTRAFFIO, GIOVANNI ANTONIO (c. 1466–1516). Giovanni Antonio Boltraffio, sometimes written Beltraffio, was a Lombard painter born into a wealthy Milanese family who worked in **Milan** with Leonardo. Boltraffio became known for his **portraits** and half-length Madonnas done in the late 1490s. Little is known of Boltraffio, but Leonardo wrote in one of his notebook pages from 1491 that **Salaì**, rumored to be Leonardo's favorite student, stole Boltraffio's silverpoint stylus. Boltraffio's beautiful *Portrait of a Youth* from c. 1495 (18.5 x 13.75 in., **oil** on walnut, Washington, D.C., National Gallery of Art) is an exceptional painting that reveals the humanity of a young boy who glances out of the painting at the viewer with softly modeled, limpid eyes. He wears a deep red overcoat, upon which his long chestnut hair cascades down his shoulders. The black background is typical of other students in Leonardo's workshop.

After Milan fell to the French Army in 1499, Boltraffio worked in Bologna for several years for the Casio family. His **paintings** are highly realistic works in the style of Leonardo but with a slightly more linear approach and less **sfumato**. The styles are similar enough, however, that throughout the years several paintings, including the ***Madonna Litta*** and the recently attributed ***Salvator Mundi***, have been attributed to either Boltraffio or Leonardo. Boltraffio's best-known work is the *Casio Altarpiece*, a large painting of the Madonna and Child seated on a low bench flanked by standing Saints John the Baptist and Saint Sebastian, and two kneeling Casio family donors. The Virgin tilts her head to gaze at the viewer in a sorrowful stare, while the Christ Child sits on her lap. An atmospheric landscape undulates behind the holy group. The rich, saturated **colors** are the result of oil paint, introduced in Leonardo's Milanese workshop. Indeed, Leonardo was influential in Milan and trained the next generation of **Renaissance** painters while there. *See also* LANDSCAPES; LEONARDESCHI.

BORGIA, CESARE (1475–1507). Spanish-Italian mercenary soldier Cesare Borgia became a cardinal when his father, Pope Alexander VI, was elected to the papacy, but he resigned after his brother was murdered. He then moved to Northern Italy, where he served as commander of the papal armies, and after receiving support from the king of France, he led the battle for Imola and Forlì against the Sforza of **Milan** to become the duke of Romagna in 1501. That same year, he marched south to defeat the Aragonese in Naples and Capua, and turned northeast to capture Urbino, however, after his father's death in 1503, Cesare fell ill and struggled to maintain power under Pope Julius II. In 1504, he was imprisoned in Spain but escaped to find favor with King John III of Navarre, who hired him to recapture territories now held by the Castilians under Ferdinand II of Aragon. One morning Cesare was caught alone in an ambush and killed with a spear.

In 1502, when it became clear that Cesare planned to march into **Florence**, Florentine leader **Piero Soderini** sent **Niccolò Machiavelli**, who was his second chancellor and political ambassador, together with Leonardo, who had just returned to Florence from Milan in 1500, to offer their services to Cesare to protect the city. Leonardo and Machiavelli traveled with Cesare from the summer through the winter and offered council, made maps, and designed military equipment. It is thought that Leonardo's *Map of Imola*, known for its unprecedented accuracy, secured Cesare's patronage of Leonardo, and later that same year, Leonardo made his *Map of Tuscany and the Chiana Valley* to help Cesare form his military strategies. The next year, likely a result of the death of Pope Alexander VI and Cesare's illness, Leonardo returned to Florence, where he received a commission for the ***Battle of Anghiari***. Ultimately, Cesare Borgia was the inspiration for Machiavelli's *The Prince*, written in 1513, which described some of the tyrannical behavior considered the norm during this time. *See also* CARTOGRAPHY; *PARIS MANUSCRIPTS*; SFORZA, LODOVICO.

BOTANICAL STUDIES. Leonardo's *Star of Bethlehem* from c. 1505–1510 is a pen, ink, and red chalk drawing on paper (7.75 x 6.25 in.) in the Royal Collection Trust in the United Kingdom that reveals his interest in the small details of the natural world. This sheet of parchment also includes smaller sketches of a wood anemone and a sun spurge that are drawn in such a way as to show their shape and movement. **Renaissance** artists carefully observed both the larger views of nature, the macrocosmic view, and the small details of the natural world, the microcosmic view, to form a full picture of the world. It was widely thought that one small part of nature implied the larger whole of the universe.

After 1500, Leonardo began to sketch detailed views of plants, from which he formed the idea that everything in the natural world shares similar universal shapes—the curved line, the spiral, the circle. The thin leaves of plants also curl and move like human and animal hair, or the flow of water. For Leonardo, it was not only plants, but also their movement, that required study to understand the underlying structure of the world, and this movement would also suggest how time passes as one observes plants. In this way, Leonardo made scientific sketches with an artistic eye that brought together both disciplines into beautiful **drawings** where an empirical study is shaped by an artistic eye and where composition and line are then idealized to create a harmonious image.

Some of Leonardo's drawings were preparatory sketches for his **paintings**, and one particular trio of flowers might have appeared in the foreground of his lost ***Leda and the Swan*** painting. An early drawing, his *Madonna Lily*, from c. 1472, now in the Royal Library at Windsor, shows Leonardo's early drawing skills in a single, beautiful flower that is similar to the lily carried by Gabriel in his ***Annunciation***. The flower is shaded to reveal the curved shape of each petal, while the petals bend and curl in different directions in a sophisticated study of depth and movement. Later on, Leonardo's botanical studies became increasingly more scientific and included annotations that identified plants and described their characteristics.

These drawings are found throughout Leonardo's **notebooks**, including the ***Codex Atlanticus***, ***Codex Arundel***, and Manuscript G of the ***Paris Manuscripts***. Furthermore, his unpublished ***Treatise on Painting*** includes a section on drawing plants called "Botany for Painters," and he also planned to write a separate treatise on plants. Leonardo's botanical studies are thought to go a step further than ancient sources, for instance, Dioscorides's *De material medica*, written in about 50 AD, which was the source for many of the medieval botanical studies, notably Albertus Magnus's (c. 1200–1280) *De vegetabilibus*. Of the many plant studies from antiquity, including those by Aristotle and Pliny, Dioscorides's study was the most extensively illustrated and remained available in Europe throughout the Renaissance. Most of these early studies focused on the identification of plants for a medical use and were the sources for late medieval and Early Renaissance herbals. Leonardo, however, did not limit his studies to describing

plants for their medicinal effects, but he also sought to show their lifelike qualities—not only their appearance and arrangement, but also their inner character as revealed through their growth and movement, which anticipates modern morphology and other branches of biology. *See also* CLASSICISM; PHYSIOLOGY.

BOTTICELLI, SANDRO (c. 1445–1510). Sandro Botticelli was a Florentine painter contemporary to Leonardo who also received patronage primarily from the **Medici** family in **Florence** during the late 1400s. Botticelli is best known for his large, mythological scenes, but he also painted **portraits** and religious images focused on the Virgin Mary. Botticelli was born in Florence, and his father was both a tanner and a worker who beat pieces of gold into the gold leaf to be used for gilt bronze and cover painting backgrounds and clothing details. This upbringing must have influenced Botticelli, who first entered the workshop of a goldsmith before beginning his studies with Fra Filippo Lippi (c. 1406–1469), one of the major Florentine painters of the first half of the 1400s.

By 1472, Botticelli had his own workshop and trained Filippino Lippi (1457–1504), the son of Filippo. The style of these three artists is similar and consists of a detailed realism done with rich **color** and small brushstrokes rather than through **light** and dark contrasts. Botticelli's figures are very linear, and the light source is evenly displayed across the painting. His use of **perspective** is minimal, and instead he focused on creating a beautiful surface with graceful lines and a harmonious composition. In this way, Botticelli's style is very different from that of Leonardo and reminds us that there was not a clear stylistic primacy in Florence during this time, but while some artists focused on the display of **linear perspective** and mathematical realism, other artists crafted a more idealized form of realism and a decoration of the painted surface.

Botticelli could have been influenced by the style of the older Gentile da Fabriano (c. 1370–1427), who brought to Florence richly painted surfaces with a profusion of gold, as seen in his *Adoration of the Magi*, done in Florence in 1423. Botticelli's *Adoration of the Magi*, commissioned for Santa Maria Novella in Florence in c. 1475 (Florence Uffizi Museum), dates about the same year Leonardo completed his ***Annunciation*** for a convent outside Florence. Botticelli's work shows a lyrical style, where the figures pose gracefully, with tilted heads and a softly swaying pose. He used gold here but more sparingly than Gentile, whose paintings were known to be extremely expensive. Portraits of the donor and members of the Medici family fill the scene, which followed a newly established tradition of blending contemporary figures into religious scenes, also found in the work of Benozzo Gozzoli (c. 1421–1497), who had just finished his murals in the Magi Chapel in the Medici Palace in Florence in 1461, with rich surface detail and gold leaf.

We see Botticelli's fully developed style in his later works, for example, his fresco of the *Youth of Moses* in the Sistine Chapel in **Rome**, commissioned in 1481, and, most famously, in his *Primavera* from c. 1482 and *Birth of Venus*, c. 1485 (both in Florence, in the Uffizi Museum). The *Birth of Venus* reveals Botticelli's understanding of Platonism and interest in the classical ideal. Here he introduced a monumental image from classical antiquity, that of Venus, the goddess of love and beauty. She is posed nude, yet modestly, and gazes out at the viewer with a tilt of her head. The wind gods are blowing her to shore as she stands on a seashell, while a springtime goddess rushes to cloak her in a beautiful flowered robe. Her blond hair blows gently in the breeze against a flat water and sky background. In this work, Botticelli offers a variant on the scientific interests of Leonardo and uses a more tempered realism, that of idealism, to honor the classical idea of grace and beauty in art, which elevates the viewer in the same way as poetry. Indeed, a contemplation of beauty was central to Platonic thought, as it was examined at the **Platonic Academy**, recently established by Cosimo de' Medici.

By the 1490s Botticelli had shifted his focus back to religious paintings, and his later works were influenced by the teaching of **Girolamo Savonarola**, who encouraged

Florentines to turn away from the corruptions of the earthly world. Botticelli's portraits were equally elegant, torso-length images done in profile or three-quarter view, set against a window or a dark background, with the exception of his *Portrait of a Man with a Medal of Cosimo de' Medici*, from 1474 (Florence, Uffizi Museum), an early work that has a watery background stretching beyond the shoulders of the man who holds a gesso medal inserted into the painting. The *Mystical Nativity* is Botticelli's last known work, from c. 1500 (London, National Gallery), and shows a spiritual image that steps back from spatial realism to highlight his theological interpretation with more spatial abstraction. Leonardo certainly would have known Botticelli and his work, and observing Botticelli's painting in the context of everything that was going on in Florence during these years would certainly have provided Leonardo with a stylistic variety from which to formalize his own ideas. *See also* CASTAGNO, ANDREA DEL; CLASSICISM; FICINO, MARSILIO; GHIRLANDAIO, DOMENICO; HUMANISM; MIRANDOLA, GIOVANNI PICO DELLA; POLIZIANO, ANGELO; POLLAIUOLO, ANTONIO DEL; UCCELLO, PAOLO; VERROCCHIO, ANDREA DEL.

BRAMANTE, DONATO (c. 1444–1514). Italian **Renaissance** architect Donato Bramante introduced a classical style of **architecture** into **Milan** and **Rome** closely linked to the aesthetic standards established by Roman engineer **Vitruvius** in his treatise *De architectura*, written in the 1st century BCE. Bramante's best-known work is the Tempietto, a small round mausoleum located inside the courtyard of San Pietro in Montorio in Rome, from 1502. Here we see three steps leading to the base of the temple, then three more steps to the colonnaded portico. Equally spaced Doric columns support a frieze of triglyphs and metopes in the classical style, and flank the entrance in a perfectly symmetrical circle. The measurement of the columns, the dome, and the height and width of the building reveal the purest Renaissance interpretation of Vitruvian proportions.

Prior to working in Rome, Bramante began his career in Milan, where he met Leonardo. Bramante was born near Urbino to a wealthy farming family and likely first studied with painter **Piero della Francesca** in Urbino, where he would have learned the importance of **geometry** and **perspective** in painting. In 1477, Bramante is documented as working in Bergamo, painting illusionistic architectural perspectives, none of which survive today. His first independent construction project was the church of Santa Maria presso San Satiro, built in Milan in 1481–1486, which is unique in that its choir was painted in a perspective view to give the impression of a much larger interior.

Throughout the 1480s, Bramante worked in Milan on various palace decorations until 1488, when Cardinal Ascanio Sforza, the brother of Duke **Lodovico Sforza**, commissioned him to design a new cathedral for Pavia. In Leonardo's ***Codex Atlanticus***, he recorded a visit to Pavia in June 1490, where he saw the *Regisole*, a bronze equestrian monument from antiquity. Bramante and Leonardo likely worked in Pavia together, while they also sought to resolve the structural problems that plagued the crossing tower, or *tiburio*, of the **Milan Cathedral** during this same time. Furthermore, Bramante also worked with Leonardo to design renovations for the piazza and ducal palace in Vigevano in 1492–1494. In Leonardo's ***Paris Manuscript*** H, fol. 65v, he noted that on 2 February 1494, he made some irrigation studies at the Sforza villa in Vigevano.

Bramante was also hired to renovate the monastery of Santa Maria delle Grazie in Milan, a Dominican convent that had just been completed by Guiniforte Solari (c. 1429–c. 1481) in 1469, at which point Lodovico Sforza decided to convert part of the church into a family mausoleum, a project that spanned the 1490s. There, Bramante introduced a new Renaissance style that blended with the existing Lombard Gothic, while during this same time Leonardo painted the ***Last Supper*** on the walls of the refectory being transformed into the Sforza mausoleum.

Like Leonardo, Bramante was part of the Sforza court, where he was introduced to humanistic ideas, poetry, and art similar to what he had experienced in the court of Urbino. He also wrote some poetry and made designs for

various royal festivals. This cultural era ended, however, at the French invasion of 1499, when Bramante fled Milan and settled in Rome to work for the papacy. There, he reconnected with Leonardo just before his death in Rome in 1514, when he asked Leonardo for advice on harbor and fortress designs at **Civitavecchia**. Leonardo's **drawings** for this project are found in the *Codex Atlanticus*, while construction was completed by **Giuliano da Sangallo**. *See also* ALBERTI, LEON BATTISTA, BRUNELLESCHI, FILIPPO; FILARETE, ANTONIO DI PIETRO AVERLINO, SCULPTURE.

BRIDGES. In Leonardo's **notebooks** there are several different portable bridge **inventions**. Some of his designs appear in the ***Codex Atlanticus***, beginning with fol. 55r, which shows a drawing from the mid-1480s, made while working for **Lodovico Sforza** in **Milan**. On the top of the folio we see a man sitting on the edge of a partially constructed bridge, roping up a piece of wood that dangles below into a new section of the bridge that will reach the other side of the river. This simple bridge design appears to be one that can be completed quickly with rope and nearby branches, and Leonardo wrote at the top of the page that it can be used to flee from or advance upon an enemy in battle. Leonardo sketched a few details of its construction on the same folio, showing how to strengthen the bridge. One drawing shows how two branches are lashed together between an x-shaped support, while another shows a clamping mechanism that can be adjusted to extend the length of the wood during construction, hooks to attach sections together, and different rope knots. This bridge design is a simple plan that could be easily replicated by following Leonardo's fundamental principles of attachment and support.

Another bridge, designed by Leonardo for **Cesare Borgia**, is a self-support bridge made solely of wood that can be carried into battle and quickly assembled across a body of water (*Codex Atlanticus*, fols. 69r and 71v). The bridge parts include crossbeams and braces with notches in them for the crossbeams to nestle into. The builder can construct the bridge quickly and add as many pieces as needed for the intended width, repeating the same construction principle for each section. This bridge is the one most commonly replicated today and ranges from large versions that can support cars to small models made of popsicle sticks that children can assemble. Another bridge type Leonardo designed is a revolving or swing bridge, made for Lodovico Sforza (*Codex Atlanticus*, fol. 855r). This bridge would be preassembled and packed to carry into battle, where it would be swung across a body of water to be set down on the opposite side. The bridge was built on wheels and could swing outward using a rope-and-pulley system, as well as a balancing device. Leonardo also designed a double-decker bridge (**Paris Manuscripts** B, fol. 23r), which was made in conjunction with his **ideal city** plans from 1487–1489, and did not serve a military function. Here, one level could be used for traffic coming into town, while the other level could be used for traffic leaving town, or one could be for pedestrian traffic, while the other for vehicular and animal traffic. Leonardo also designed various permanent canal bridges as part of his studies of water and river diversion projects. Other inventions include a sluice gate similar to modern versions, where a boat enters a canal, the gate is lowered, water flows into the canal to raise its height, and the upper gate is opened once the water is leveled.

Leonardo's largest bridge was his Golden Horn bridge, designed in 1502, in a series of sketches in the Paris Manuscripts L, fols. 65v and 66r. In 1502, Bayezid II (1447–1512), sultan of the Ottoman Empire, came to **Rome** to hire engineers to design a bridge that could span the Golden Horn, an inlet off the Bosporus from the Marmara Sea that runs through the middle of Istanbul. Leonardo's design was a masonry bridge somewhere between 720–1,200 feet long and tall enough for a ship to sail beneath. The sultan rejected Leonardo's plan as unfeasible, and the plan was lost until 1952. Then, in 2001, Norwegian artist Vebjørn Sand constructed a bridge based on Leonardo's designs, which is a pedestrian bridge located over highway E18 in the town of Ås, Norway, outside Oslo.

Called the Vebjørn Sand da Vinci Project, this wooden bridge is shaped in a parabolic arch. *See also* AUTOMATON, BOATS, CANNONS; DIVING SUIT; ENGINEERING, INVENTIONS; SCYTHED CHARIOT, 33-BARREL ORGAN; TANK; WHEEL-LOCK MUSKET.

BRONZE CASTING. *See* CHEMISTRY, DONATELLO; GHIBERTI, LORENZO, SCULPTURE; VERROCCHIO, ANDREA DEL.

BROWN, DAN (b. 1964). Fiction writer Daniel Gerhard (Dan) Brown is known for his best-selling thriller novels inspired by historical themes set in **Renaissance** and Baroque cities in Europe. Several of his books have been made into movies. Each book is an action-packed treasure hunt where numerology, symbolism, religious beliefs, and conspiracy theories shape the narrative. *The Da Vinci Code*, published in 2003, features a fictional Harvard professor named Robert Langdon and cryptographer Sophie Neveu of the French National Police, who are trying to solve a murder in the Louvre Museum. Brown stages the murder victim in a pose similar to Leonardo's ***Vitruvian Man*** but with a pentagram carved into his chest. The two protagonists explore, through decoding cryptic textual and numeric messages, the motive for this murder, which involves locating the Holy Grail.

Although the book is only loosely connected to the ideas of Leonardo, one of the characters explains to Neveu that the long-haired, youthful figure of John the Evangelist, seated to Christ's right side in Leonardo's ***Last Supper***, is actually Mary Magdalene. The author explains that the lack of a chalice in the painting refers to Christ's knowledge that Mary herself was the Holy Grail, the holder of the sacred blood of Christ, and Christ's bloodline was carried into contemporary times where Neveu is revealed to be a descendent through the Merovingian Dynasty.

In the novel, Leonardo knew the secret of the Holy Grail through his membership in the fictitious Priory of Sion, a secret, hoax society founded in the mid-1900s. This society inspired many pseudohistorical novels of the 20th century through its false association with a secret chivalric order from the First Crusade to establish a royal lineage stretching back to Christ and forward through European aristocracy. A fictional list of grand masters of this organization included famous French alchemist Nicolas Flamel (c. 1340–1418); Florentine painter **Sandro Botticelli**, and Leonardo, who supposedly became a member in 1510. Later grand masters included Isaac Newton, Victor Hugo, and Claude Debussy. It is this fictitious link to Leonardo that Dan Brown crafted in his novel. Although widely known to be historical fiction, the book became controversial when Brown claimed the majority of his book was factually accurate, and the notion that Mary Magdalene was at the Last Supper gained traction. Despite this controversy, Brown's novel has nonetheless brought Leonardo and his *Last Supper* into the forefront of popular discussion. *See also* ASTRONOMY, GEOMETRY; MATHEMATICS; VITRUVIUS, MARCUS POLLIO.

BRUNELLESCHI, FILIPPO (1377–1446). Italian **Renaissance** architect Filippo Brunelleschi was born in **Florence** and trained in **mathematics** and literature to follow his father's profession as a notary. Like his father, the young Brunelleschi was also interested in **architecture** and paid attention to the construction of the Cathedral of Florence, which he witnessed being built throughout his childhood. Brunelleschi then began training as a goldsmith, completing his education in 1398, and in 1401, he entered a competition for a set of bronze doors for the Florence Baptistery, a contest he lost to contemporary goldsmith **Lorenzo Ghiberti**. Soon thereafter, Brunelleschi and his friend **Donatello** went to **Rome** to join the lucrative trade in antiquities, and there he began to study ancient architecture. When they returned to Florence, Donatello initiated his independent career in **sculpture**, while Brunelleschi received his first architectural commission after winning the 1418 competition for the Florence Cathedral dome, where he developed many technical advances needed to complete this large dome in a massive construction project that dominated his life. A year later, he also received a commission for the orphanage called the Ospedale degli Innocenti,

where he introduced the architectural language of classical antiquity in Florence.

To navigate the complexity of the dome construction, Brunelleschi established a new technique to span the drum of the dome, and he invented new scaffolds, hoisting machines, and a river barge needed for transporting construction materials. In this way, he is considered the first architectural engineer since ancient Roman military engineer **Marcus Pollio Vitruvius**, called Vitruvius, whose treatise *De architectura* provided practical advice as well as the first known discussion of architectural aesthetics. This treatise was rediscovered in 1414, by Florentine scholar Poggio Bracciolini (1380–1459), and studied extensively by **Leon Battista Alberti**. Brunelleschi would certainly have known Vitruvius's ideas, and his visit to Rome, where he made scale drawings of numerous buildings from antiquity, provided him the skills to become the most influential architect in Renaissance Italy.

Construction on the dome continued after Brunelleschi's death, when, in 1472, **Andrea del Verrocchio** soldered together a large, gilded copper ball that was placed on top of the now-complete lantern. Perhaps the young Leonardo, who worked in Verrocchio's studio at the time, was present when the ball was hoisted to the top of the lantern with a hoisting machine invented by Brunelleschi. It was certainly Brunelleschi's interest in machinery, mathematics, antiquity, and aesthetics that most influenced Leonardo. Brunelleschi also designed military fortifications for Florence and a large barge needed to transport marble. The sinking of Brunelleschi's barge, designed to carry marble from the quarries of Carrara down the Arno River to Florence, was an event Leonardo would have heard about.

Brunelleschi was also interested in mathematical **perspective** and developed a theory of one-point perspective, which Alberti codified in his treatise on painting. This perspectival system was enormously influential on Leonardo's development of pictorial space. Leonardo also sketched several of Brunelleschi's inventions, including his revolving hoist, called an elevator, found in the ***Codex Atlanticus***, fol. 138r, and his **crane** (fol. 965r). Leonardo's folding scaffolds, made for his wall mural in the Palazzo Vecchio in Florence, were inspired by Brunelleschi's transport machines, and Leonardo's work in military **engineering** was based on Brunelleschi's ideas. *See also* CLASSICISM, INVENTIONS, OPTICS.

BUCCLEUCH MADONNA. *See MADONNA OF THE YARNWINDER (BUCCLEUCH).*

BUCKET-WHEEL EXCAVATOR. *See* CRANES; ENGINEERING.

BURLINGTON HOUSE CARTOON. *See VIRGIN AND CHILD WITH SAINT ANNE AND SAINT JOHN THE BAPTIST.*

C

CALCULATOR. *See* ADDING MACHINE.

CAMSHAFTS. *See* ENGINEERING.

CANAL LOCK. Of the many **inventions** theorized by Leonardo, his studies of water laid the foundation for his ideas on how to move water via river diversion projects, dams, canals, and dykes. He theorized large moveable dykes that could protect the Republic of **Venice** from invasion, but these ideas were too expensive to ever be constructed. Other studies had more practical value, for instance, his canal locks. One example is seen in a pen and ink drawing in the ***Codex Atlanticus***, that shows a design for a canal bridge made for **Lodovico Sforza** of **Milan** in about 1495, while another drawing shows a canal lock called a miter lock, designed for San Marco in Milan in 1497 (*Codex Atlanticus*, fol. 90v). This lock type is still used today and is lighter than previous portcullis canal locks and can be lifted by one man instead of two. This drawing shows the lock mitered together at 45 degrees, with quoin posts, wood door planks braced by wood beams, and iron covered joints above a brick flooring. The gate folds into a recessed wall so the water can flow smoothly. Leonardo drew a similar lock in the ***Codex Arundel***, fol. 264v, from c. 1517, which was designed for a canal in France.

Locks had been studied by **Francesco di Giorgio Martini** and **Leon Battista Alberti**, and although Leonardo certainly knew these contemporary sources, they first appeared in antiquity, when shallow rivers were dammed to increase their height, thereby allowing the passage of boats that could not ordinarily travel on shallow water. The earliest dams were weirs, or horizontal barriers placed across a river that could also be used to prevent flooding, but boats could not easily navigate past these blockades, so a flash lock was the first type of lock devised, where the dam had a small opening barricaded by wooden plank doors that could be lifted up to allow a boat to pass through, propelled by the torrent of water that streamed through the opening. Somewhat dangerous because the violent water flow could sink a boat, this type of dam was soon replaced by other types of gates, for example, staunch and pound locks. The portcullis, or sliding door lock, was the medieval door type that preceded the miter lock. *See also* CLASSICISM; ENGINEERING, WATER STUDIES.

CANALS. *See* ARCHITETURE, BORGIA, CESARE, CARTOGRAPHY; CIVITAVECCHIA; CLOS LUCÉ; CRANES; ENGINEERING; HYDRAULICS, IDEAL CITY; ROME, ROMORANTIN; VENICE; WATER STUDIES.

CANNONS. Leonardo's large pen and ink drawing of a *Cannon Foundry*, dated 1488 and located in the ***Windsor Folios*** collection (United Kingdom, Royal Collection Trust), reveals his interest in the highly technical process of metallurgy and the production of cannons. Here we see clusters of nude men climbing up to pull four sets of levers while several more men adjust the wheels, demonstrating the brute strength required of this profession. Leonardo drew the men without

clothing, perhaps to show the anatomical details of the physical strain of this type of work. Leonardo was interested in the explosive power of weaponry and worked in military technology throughout his life, where he invented the **wheel-lock musket**, an armored **tank**, and a **33-barrel organ** to attack the enemy, in addition to portable **bridges**, dykes, and canal systems to evade the enemy.

Cannons were first used by English soldiers in the mid-1300s, and they propelled medium-sized stone balls by the explosive power of an ignited powder. By the **Renaissance**, little had changed since then, except that by the 1400s cannons were slightly larger, made of cast iron or bronze, yet they still propelled cannonballs from the mouth of a short, heavy barrel a fairly short distance. Leonardo first devised a breech-loading cannon where cannonballs were loaded in the back of the barrel rather than the earlier muzzle-loading cannons, which were much slower, as men were required to load the cannonballs into the front of the barrel and guide them back down the hot barrel chamber and into place for firing. He also suggested cooling the cannons with a vat of water after several firings, which reduced the danger of premature explosions and increased accuracy of propulsion. In this way, three cannons could be used in rotation, with one being fired, one being loaded, and one being cooled. This led to Leonardo's triple-barrel cannon, which served the same function, but it was built as one firing machine to increase its portability. Leonardo also experimented with this concept in his 33-barrel organ, which is considered a prototype for the modern machine gun.

Next, Leonardo invented the steam cannon, made from copper. The loading, or breech, end of the cannon would have been built into a brazier stocked with hot coals, and after an iron cannonball was loaded, water would be injected behind the ball, which would turn to steam and propel the ball through the barrel. It is not clear if this type of cannon was ever built or used, however, although Leonardo did provide fairly specific information on the appropriate size of the cannonball and how far it should travel. He also experimented with different types of cannonballs and filled some with gunpowder, which would explode on impact to scatter smaller pieces of metal and stone, as seen in the fireball design found in ***Paris Manuscript*** B, fol. 4r. Integral to these technological advances was Leonardo's wheel-lock, which provided an automatic way of igniting gunpowder without the cumbersome and dangerous match cord, which could either ignite prematurely or, more commonly, be too damp to ignite.

Finally, Leonardo studied how to propel cannonballs farther by first measuring their rate of speed at different angles of projection so that he could see if different materials or weights could improve projection distance and accuracy. These studies were not specific to cannons but were also integral to Leonardo's designs for catapults, which were more quick loading than medieval versions that did not use gunpowder, so they could be mounted on walls. Here, a man could climb a ladder and load a cup with a large stone. The cup was attached to a rope, which was pulled back with a lever and released with a pin. The slingshot was also still widely used in warfare and acted as a handheld portable catapult. A multiple sling is found in the ***Codex Atlanticus***, fol. 159r. With these advances in weaponry, and especially the cannon, fortifications began to be adjusted with taller and wider rampart walls to account for the increase in cannon projection. *See also* ARCHITECTURE; ANATOMY; AUTOMATON; BOATS; BRIDGES; CANNONS; DIVING SUIT; ENGINEERING; INVENTIONS, SCYTHED CHARIOT.

CAPILLARY ACTION. *See* HYDROSTATICS.

CARDANO, FAZIO (1444–1524). Fazio Cardano was a professor of **mathematics** and a lawyer at the University of Pavia, known to be a friend of Leonardo. He was also the father of **Girolamo Cardano**. In 1482, Cardano translated John Peckham's (c. 1230–1292) treatise on **optics** called *Perspectiva Communis*. Peckham, the archbishop of Canterbury, studied optics and **astronomy**, in addition to theology. Leonardo owned a copy of Peckham's book (mentioned in ***Madrid Codex II***,

fol. 2v), and he mentioned Cardano in several of his **notebooks**, having consulted him during his studies of **geometry**, **perspective**, and optics in **Milan**. *See also* ALBERTI, LEON BATTISTA; ARCHITECTURE; BRUNELLESCHI, FILIPPO; CARTOGRAPHY; CLASSICISM, PACIOLI, LUCA; PIERO DELLA FRANCESCA.

CARDANO, GIROLAMO (1501–1576). Girolamo Cardano, the son of **Fazio Cardano**, was an Italian **Renaissance** mathematician known primarily for his studies of probability and algebra. He was hired in 1547, at the University of Pavia, as a professor of medicine, and in 1551, he published *De Subtilitate Rerum*. Cardano was interested in many fields of study and is credited with inventing the combination lock and the Cardan shaft, or drive shaft, which is illustrated in Leonardo's manuscripts, along with a universal joint. Although the younger Cardano likely never met Leonardo, his ideas demonstrate a familiarity with Leonardo's notebook **drawings**, which the younger Cardano could have seen at **Francesco Melzi's** villa outside **Milan**. In his *De Subtilitate Rerum*, Cardano describes the art of painting by echoing the words of Leonardo, and he credits Leonardo with advancing the study of **anatomy**. *See also* ALBERTI, LEON BATTISTA; ARCHITECTURE; BRUNELLESCHI, FILIPPO; CARTOGRAPHY; CLASSICISM; GEOMETRY; MATHEMATICS; PACIOLI, LUCA; PIERO DELLA FRANCESCA.

CARICATURES. Many Italian **Renaissance** artists of the late 1400s, influenced by the ideal proportions of the human body from classical antiquity, began to experiment with the exaggeration of physical features to show bizarre and unsightly figures. Leonardo and **Michelangelo** both drew caricatures, sometimes called grotesques, but Leonardo's sketches were more extensive than most other artists. **Giorgio Vasari** claimed Leonardo was fascinated by people with strange heads, and he studied their faces to further exaggerate their features in a series of sketches. He called these heads "visi monstruosi" and used these studies to further explore the variations found in human physiognomy.

Oftentimes these figures were comical, while sometimes they were meant to show evil. In *Five Caricature Heads*, c. 1490, ink on paper (**Florence**, Accademia), Leonardo shows four male heads and one female, all turned in different directions to show various exaggerated features. These include a man with a bulbous, upturned nose and mouth, another male with a crooked nose and pronounced underbite; a woman with a malformed forehead, a man with a pointed, broken chin, and another man, likely a priest, with his monastic hood behind his shoulders, shown in a three-quarter profile with a slight cleft chin and large nose but without exaggeration. These human studies range in their depiction of a variety of features from within the realm of normal to those considered grotesque.

Conversely, beauty was the prevailing aesthetic ideal in the Renaissance, and physical beauty was considered to reveal the inner goodness of a person with a superior sense of morality and intellect. The model of female beauty was the Virgin Mary, who many noble women of the Renaissance sought to emulate in her physical appearance, as expressed in Renaissance art, and her demeanor, as explained in devotional books and sermons. Beauty was the artistic goal, then, and it harked back to classical antiquity in its construction. Many artists therefore studied the grotesque to not only assess the wide variety of human proportions, but also provide visual display of evil or ignorance, for instance, the sinners or disbelievers in the Bible, or the traitors in historical battle scenes. *See also BATTLE OF ANGHIARI*; *CHRIST CARRYING THE CROSS*; CLASSICISM.

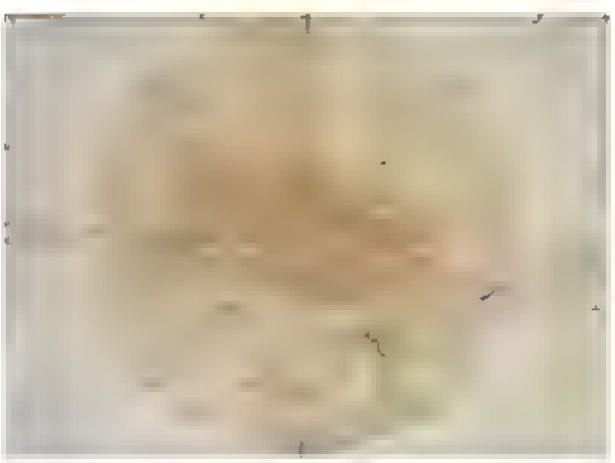
CARTOGRAPHY. In 1502, Leonardo made the first known ichnographic map, a *Map of Imola*, which features an aerial view of the town of Imola outside of Bologna in Northern Italy (17.3 x 23.7 in., pen and ink with colored wash over black chalk, Windsor, Royal Library, RCIN 912284). The town is seen from a single point above looking down, creating a perpendicular aerial view. Imola was founded in about 82 BCE, under Roman emperor, Sulla and was an agricultural center in the ancient region of

Romagna northeast of **Rome**. Some of the ancient street grid pattern is evident in Leonardo's map, as are the fortifications built by the Visconti family, rulers of **Milan** in the 1400s. In 1499, **Cesare Borgia's** troops conquered Imola, while Cesare, who had met Leonardo in Rome, commissioned Leonardo to create this map so he could see his new territory.

Considered one of the most realistically accurate maps of the **Renaissance**, Leonardo used his new surveying tool, a surveyor's wheel, sometimes called a hodometer, to measure distances between objects more accurately, and a magnetic compass to derive the directional points correctly. After carefully drawing each street, building, and parcel of land, walls, and moat, Leonardo derived a center point for the map and mathematically extrapolated the angle of view from above the center point. This came to be called the bird's eye view. In this way, Leonardo created an aesthetically pleasing map with an unprecedented clarity of detail.

Leonardo owned several ancient and medieval maps, and he also borrowed other maps and drew many landscape views during his travels. Some of his landscape views, for example, the ***Arno Valley Landscape*** around **Florence**, could function as maps, while his view of Milan in the ***Codex Atlanticus***, fol. 199v, shows the city at a raking angle known as an oblique **perspective**, drawn together with the outlines of an ichnographic plan measured in a circle that shows distance relationships between buildings. These maps also reveal a greater distance between the artist's viewpoint and the vista, which is more difficult to achieve Moreover, Leonardo often included the waterways entering a city, where he sometimes drew in plans for new canal systems. When labeling street, building, and gate names in his view of Milan, he wrote the names as if he was standing in the middle of the city and turning in a circle, so the names are sometimes inverted or at angles.

His *Map of Tuscany and the Chiana Valley*, c. 1502 (15.2 x 19.2 in., black chalk, pen, and ink on parchment, Windsor, Royal Library, inv. 912278) is a good example of the type of map that requires the extrapolation of a bird's eye view, perhaps from a 45-degree angle at a mountain top, converted to a 90-degree angle to create an aerial view. This map shows the valley around Arezzo, south of Florence, in the Apennine Mountains, where Leonardo could have theorized this new viewpoint. This map was likely done for Cesare Borgia, perhaps as a strategic map, since the rivers and towns are identified, or it could have been done when Leonardo was hired to explore the possibility of damming Lake Chiana and building a canal from Florence to the ocean. Leonardo's maps were often used to survey land for city growth and territorial acquisitions. In this way, Leonardo combined his optical studies, careful observation, and mathematical skills to create a new type of map that anticipated modern mapmaking. *See also* ALBERTI, LEON BATTISTA; ARCHITECTURE; BRUNELLESCHI, FILIPPO; CLASSICISM; GEOMETRY; HYDRAULICS; LANDSCAPES; MATHEMATICS; OPTICS; WATER STUDIES.



Leonardo da Vinci, *Map of Imola*, 1502, pen and ink with color washes on paper, 17.3 x 23.7 inches, London, Royal Library, Windsor Castle.

CASTAGNO, ANDREA DEL (c. 1419–1457). Andrea del Castagno was a Florentine painter who worked in the mid-1400s, a generation before Leonardo. Little is known of his early life, but he was born in the small town of Castagno outside **Florence** and worked in Florence for the **Medici** before dying prematurely of the plague. In Florence, he made sketches of the men who were hanged upside down outside a

window of the Palazzo del Podestà, now called the Bargello, after the Battle of Anghiari in 1440. Some were citizens who escaped to join the Milanese, while others were captains of the army who escaped with the pay meant for their soldiers. These sketches are all that remain of a now-lost fresco Andrea painted on the outside walls of the Bargello, commissioned to scare the enemies of the Medici. This gruesome work made Andrea notorious in Florence, where he came to be called "Andrea degli Impiccati."

Although these types of drawings were meant to shame the families of the traitors, Andrea's sketches were also interesting studies of the human body in motion, twisting and turning awkwardly in poses that challenged the artist. Some men are wearing their military attire, while others are nude. Their arms reach out and their heads look down, visible to the viewer at a sharp angle with a lost profile. In 1479, Leonardo drew a sketch of **Bernardo di Bandini Baroncelli**, a fugitive from the Pazzi Conspiracy, who aided in an attempt to overthrow the Medici in 1478. Such sketches of hanged men seem particularly gruesome by modern standards, but during this time period they offered artists an opportunity to align themselves with the victor while studying the way a body appears in such duress

Andrea also painted a *Last Supper* **fresco** in the convent of Sant'Apollonia in Florence in 1445–1450, which is his most famous work. Here we see a well-preserved fresco that shows Christ seated at a table flanked by the apostles, while Judas sits across the table from Christ. Each apostle moves and gestures, and they turn to talk with one other or contemplate what .s taking place. While their poses are more restrained, in the manner of **Piero della Francesca**, Leonardo's later ***Last Supper***, done in the Convent of Santa Maria delle Grazie in **Milan** in the mid-1490s, shows a softer realism and more authentic display of emotion among the apostles. Certainly, Leonardo would have been familiar with Andrea's version and chose a similar table setting lined with apostles flanking Christ. *See also* ANATOMY; BOTTICELLI, SANDRO; DRAWINGS; GHIRLANDAIO, DOMENICO; MASACCIO, POLLAIUOLO, ANTONIO DEL; UCCELLO, PAOLO; VERROCCHIO, ANDREA DEL.

CASTIGLIONE, BALDASSARE (1478–1529). Baldassare Castiglione was an Italian courtier and scholar whose *Book of the Courtier* was first published in **Venice** in 1528. Written in the form of a dialogue in the ancient Greek tradition, Castiglione's book is an imagined conversation between Elisabetta Gonzaga, the daughter of Duke Federico I Gonzaga of **Mantua** and wife of Duke Guidobaldo da Montefeltro of Urbino, and Emilia Pia di Carpi, the wife of Antonio da Montefeltro, concerning appropriate behavior in a **Renaissance** court.

Castiglione was born outside Mantua, where his father was a prosperous landowner and nobleman distantly related to the Gonzaga family. He studied in **Milan** briefly, until the death of his father required him to return home and represent his family in the court of Mantua by traveling in the royal cortege to official events. After meeting Guidobaldo da Montefeltro in **Rome** in 1504, he was allowed to leave the Gonzaga court and move to the court of Urbino, which was widely seen as the most sophisticated court in Italy, hosting numerous and important cultural events in the region and holding one of the largest libraries in Europe. Castiglione continued to travel widely, often to Rome, but also to Spain as the ambassador of the Catholic Church. He was in Toledo when Rome was sacked by French and Spanish soldiers in the Sack of 1527, and he was called to respond to an accusation that he should have warned the papacy, but the matter was eventually settled and Castiglione stayed in Spain, where he died of the plague two years later.

Castiglione's book takes place in 1507, and was written from the point of view of a noble Renaissance humanist scholar and courtier. He modeled his discussions on Cicero's *Duties of a Gentleman*, as well as his *De Oratore*, which had just been rediscovered in 1421. *De Oratore* focuses on the question of whether rhetoric is a skill that can be learned or if a person is born with the ability. This concept was adopted by **Michelangelo**, who suggested that the same is true of the artist. Art

students can achieve a high level of technical proficiency, but a true genius is a person born with a God given talent. Leonardo, in his **note books**, often sought to marry these humanist ideas with the notion of the courtly gentleman, and he also promoted the idea that a worthy person is well skilled in many different disciplines, including **music**, drawing, and poetry. To these pursuits Leonardo added his scientific interests, which are not discussed in Castiglione's book.

Like Leonardo, Castiglione also added a *paragone* on painting and **sculpture**, and here Castiglione echoed Leonardo's ideas found in his ***Treatise on Painting***, written at about the same time. Leonardo argued in favor of the superiority of painting over sculpture by explaining that painting is a mental pursuit, while sculpture is a manual labor, while Castiglione left the matter open for discussion, although he seemed to favor painting. Castiglione also described the appearance of the ideal courtier, who must be young but with a mature personality and a thoughtful demeanor. A courtier must wear subdued colors rather than bright clothing so as to appear humble yet respectful. This idea is seen in many of Leonardo's **portraits**, including his most famous, ***Mona Lisa***. Here the young noblewoman wears a rich brown dress lined with thin gold embroidery around the neckline and a robe covering her sleeves. His entire palette is monochromatic. Lisa's veil barely appears to cover her hair, while her hands are carefully positioned in a graceful and elegant manner but without any rings. Clearly, her hands are the soft, delicate hands of a woman who does not participate in manual activities, but she also does not need to promote her status with gold jewelry. The origins of these ideas are impossible to ascribe to either Castiglione or Leonardo, but instead they seem to be part of a larger cultural context in this elevation of the artist, which occurred in the Renaissance. *See also* CLASSICISM; HUMANISM.

CATAPULT. *See* CANNONS; INVENTIONS.

CATHOLICISM. Catholicism was the only Christian Church during the time of Leonardo, who lived in the era right before the Protestant Reformation. Within the Church hierarchy, the pope, who is based in **Rome**, is the international head and governs the organization, together with the Roman Curia, or cabinet, which consists of cardinals, bishops, and lower levels of clergy, who oversee dioceses and parishes. Catholics believe there is one God, who exists in a Holy Trinity that includes Jesus Christ (God the Son) and the Holy Spirit, and the role of the Church is to spread the sacrament of salvation to all humans through the teachings of Jesus Christ. The life of Jesus, from his birth, teachings, suffering, and resurrection, is widely illustrated in visual images used as both educational (didactic) and devotional (iconic) guides for the audience. The devotions of the Virgin Mary and other saints are also illustrated for use by both the clergy and the lay audience, who focus their prayers on these works and use them to remember biblical stories.

During the time of Leonardo, the Catholic Church played a central role in art commissions, from **paintings** and **sculpture** used in Church liturgy to architectural commissions, and most artists worked for the Church as their primary patron during the **Renaissance**. Leonardo's earliest commissions in **Florence** were for local churches and monasteries before his subject matter shifted to portraiture, favored by private patrons, and once he began to work for the **Medici** and the Sforza, his religious commissions were less frequent. Nonetheless, **Lodovico Sforza** commissioned Leonardo to paint the ***Last Supper***, and Leonardo also worked for the Medici pope **Leo X** in Rome, as these prominent families tended to work closely with the papacy to solidify their power.

During Leonardo's time in Rome, Pope Leo X continued the work of his predecessor, Pope Julius II, in rebuilding the Basilica of Saint Peter's and revitalizing the city as the seat of the papacy, while also seeking to expand the Catholic Church into the Americas, Asia, and Africa. Thus, this era was a time of incredible growth, with many opportunities for artists to shape their careers through an engagement with the Church. In the 1500s, the subsequent colonial rule of these new territories dramatically shaped European art, while

the Protestant Reformation in Northern Europe offered a new way of interpreting Christian beliefs separate from the administrative control of the Catholic Church. Leonardo's career was on the cusp of these dramatic changes, and he benefitted greatly from Church patronage and was informed by both his own beliefs while also looking toward new scientific models that used empirical evidence to explain the mysteries of the universe. *See also* CLASSICISM; HUMANISM.

CELLINI, BENVENUTO (1500–1571). Italian Mannerist artist Benvenuto Cellini was born in **Florence** and is best known for his autobiography. He was known for his fiery temper and inability to maintain civil relationships with other artists and his patrons, which makes his autobiography particularly interesting. Cellini was trained as a musician, but early on he preferred to work as an apprentice to a goldsmith. After a few years of travel as a journeyman, he settled in **Rome**, where he made silver and gold objects for the papacy while also working as a court musician. After the Sack of Rome in 1527, Cellini was acknowledged for his bravery in fending off attacks in Rome, and he was invited back to Florence and pardoned for his early transgressions. There he continued to lead a tumultuous life and murdered his brother's killer, as well as a rival goldsmith. He nonetheless continued to find work, even after he narrowly escaped death from an accusation that he stole gems from the papal tiara in Rome. Soon thereafter, Cellini moved to France and began to work for King **Francis I** at Fontainebleau, but scandal continued to follow him, however, he was still able to return to Florence to work for Duke Cosimo I de' **Medici**, who commissioned two of his most famous works, a portrait bust and the freestanding bronze sculpture of Perseus and Medusa, located in the Loggia de' Lanzi next to the Palazzo della Signoria in Florence.

Cellini's *Saliera* (*Salt Cellar*), an enameled gold salt container made as a table decoration, is his most sumptuous work. Completed in 1543, for Francis I, the elaborate small sculpture shows the god and goddess of the earth and ocean reclining on the base of the container, which is encrusted with gems and painted gold. It is now worth $60 million. Cellini was in France several decades after Leonardo's death, but, in 1542, he purchased a copy of one of Leonardo's **notebooks** from a member of the court of Francis I, a now-lost book on **perspective** that was to be included in Leonardo's planned ***Treatise on Painting***. Leonardo's *Treatise on Painting* is now part of the *Codex Urbinas*, but it does not include a section on perspective, which could have been separated out and left in France. Cellini described this perspective treatise as the most beautiful study a man had ever made and explained that Leonardo showed how objects are foreshortened in not only depth, but also width and height, to reveal a more sophisticated curved perspective. Cellini showed the treatise to architect Sebastiano Serlio (1475–c. 1554), while painter and theoretical writer **Giovanni Paolo Lomazzo** also saw the work and described Leonardo's perspective study as difficult to understand. Thus, Cellini's comments provide important clues to this lost study by Leonardo. *See also* ATMOSPHERIC PERSPECTIVE; LINEAR PERSPECTIVE; MATHEMATICS, MUSIC; SCULPTURE.

CESENATICO. *See* BORGIA, CESARE, VENICE.

CHÂTEAU D'AMBOISE. *See* CLOS LUCÉ.

CHEMISTRY. Of the numerous types of experiments Leonardo performed to better understand the world around him, many were chemical experiments that helped Leonardo further his artistic innovations. For example, since antiquity, artists combined heated and cooled pigments and other materials needed to create works of art, and Leonardo built upon this proto-chemistry, or alchemy, as it is sometimes called, through experimentation with **tempera** and **oil** pigment recipes and wall plasters, as well as new bronze casting techniques. Leonardo's interests followed Aristotle's observation that elements were formed from earth, air, fire, and water, and humans could learn about the world through their senses. From Aristotle and Plato, medieval theologians added a God-centered interpretation of the world, while

Arabic scholarship began to filter into Western Europe in the later Middle Ages, bringing more sophisticated scientific observations.

By the **Renaissance**, Leonardo had begun to notice inconsistencies with contemporary alchemical observations through his own examination of the four elements. He noted that nature produces things that man can combine to create more complex compounds but that older alchemists had failed to generate any new compounds not already found in nature because of their fixation on producing gold; therefore, Leonardo sought to create things useful for humans, including the creation of salt by distilling feces. For this, he sketched a plan of a furnace needed for distilling nitric acid, as well as an apparatus for continuous cooling by water flowing through a tube. Like earlier painters, Leonardo's chemical studies were motivated by the desire to create new art materials, mainly pigments, but some of these pigments had medicinal purposes as well, which is why painters were originally admitted into the physician and pharmacists' guild in **Florence**, called the Arte dei Medici e Speziali.

In addition, Leonardo correctly intuited the existence of atoms in his description of small, natural points, a theory he devised while experimenting with combustion, in anticipation of the work of Robert Fludd (1574–1637), and through experiments with distillation. Distillers were used during Leonardo's time for alcoholic drinks and perfumes, but Leonardo designed a distiller that had a wide condensing surface kept cool with an external tank filled with cold water, as seen in a sketch in the ***Codex Atlanticus***, fol. 989. A model of this distiller, together with other examples of Leonardo's experiments, is found today at the Museo Nazionale Scienza e Tecnologia Leonardo da Vinci in **Milan**. Like most Renaissance artists, Leonardo was also interested in metallurgy due to his training in bronze casting in the studio of **Andrea del Verrocchio**. While Verrocchio cast numerous freestanding bronze sculptures throughout his life, Leonardo's attempts to cast a colossal equestrian figure group in Milan was unrealized in 1499, when the French invaded Milan and the huge amount of bronze purchased for the horse and rider was used for military **cannons**. *See also* COLOR; ENGINEERING; FICINO, MARSILIO; INVENTIONS; MUSEUMS; SCULPTURE.

CHERAMY VIRGIN OF THE ROCKS. *See* GIAMPIETRINO.

CHIAROSCURO. Leonardo's desire to create volume and depth in his **paintings** led him to use numerous techniques of **color** and line application in his works. He was one of the first artists in history to achieve tonal consistency, where an object or figure is shown in one color shaded lighter or darker to create volume. Previous artists depicted volume through color modeling, where shifts in color represented three-dimensional space. Shading with **light** and dark allows for greater color unity that is more realistic. This technique came to be called chiaroscuro, which means light-dark (clear and obscure) in Italian, where the contrast between the two reveals the swelling forms of volume. Chiaroscuro can be either very subtle or very dramatic and was most successfully used in the **Renaissance** with **oil** pigments that could be layered and graduated.

Most of Leonardo's works demonstrate chiaroscuro, but his ***Mona Lisa*** is one of the most famous examples of its use. Here we see chiaroscuro in the soft modeling of the hands and face, where the sitter's golden skin tone suggests the fleshy warmth of a living person. A dark shadow appears beneath her chin to show where her face projects forward from her neck, and her hands rest one on top of the other, with her rounded fingers pressing into the sleeve of her dress. Leonardo restricted his color choices in this work so that his chiaroscuro is best revealed through warm earth tones. Leonardo's chiaroscuro anticipated its more dramatic use in the Counter-Reformatory Roman Baroque paintings of such Italian artists as Michelangelo Merisi da Caravaggio (1571–1610). *See also* OPTICS; TEMPERA.

CHRIST CARRYING THE CROSS. A painting of *Christ Carrying the Cross* is attributed to Leonardo by its private owner, Luke Brugnara, in San Francisco, based on its **caricatures**, which resemble many of the figures in

Leonardo's **drawings**, including the ***Battle of Anghiari*** sketches. Here we see a cropped view of Christ clutching a heavy cross that hangs diagonally across his shoulder. Two men taunt him and raise their fists at Christ while grimacing at him with their mouths open. Christ looks down toward the ground with no expression on his face, humble and reposed. The background features a silver-gray sky. Another hand reaches up toward the back of Christ's head, while the close-up view of the subject provides a tight composition and a restricted view of the scene, giving an oppressive tone to the work.

A variation on this scene is found in a painting attributed to Leonardo's student, **Marco d'Oggiono**, located in the J. Paul Getty Museum of Art in Los Angeles, showing Christ's head and hand in a similar pose. Leonardo scholar **Carlo Pedretti** first attributed this first painting to Leonardo and dated the poplar panel at about 1500, while other scholars attribute the work to an unknown painter who had direct access to the Anghiari drawings, which were widely copied throughout the 1500s and 1600s. Three other **paintings** of this exact scene exist, and Pedretti has suggested that all four were done in Leonardo's workshop, perhaps with instructional intervention from Leonardo himself. This closely cropped subject was widely depicted in **Renaissance** paintings by other artists, notably Venetian painter Titian (c. 1505, **oil** on canvas, Scuola Grande di San Rocco, **Venice**). A *Christ Carrying the Cross* attributed to Hieronymus Bosch from c. 1515 (Ghent, Museum of Fine Arts) shows more of the caricatured faces.

The Renaissance view of physiognomy specified that a person's inner character was visible in his or her outward appearance, so a twisted face, a grimace, and poor body proportions symbolized immorality. These ideas were based on Aristotle's text *Physiognomics*, which survived in the Middle Ages in a **Latin** translation, and scientific manuals from the 1400s show examples of such malformed figures, interpreted as revealing such moral impurities as deceit, lust, and other forms of evil. A later painting of *Christ Carrying His Cross*, attributed to **Giampietrino** from c. 1510–1530 (London, National Gallery), reveals the influence of Leonardo's **chiaroscuro** but in a different composition that shows a cropped figure of Christ, standing alone, surrounded by darkness. While this first painting is clearly related to Leonardo's oeuvre through these copies and related works, most scholars do not accept its attribution to Leonardo. *See also* CATHOLICISM; CLASSICISM; LEONARDESCHI.

CIVIL ENGINEERING. *See* BRIDGES; CANAL LOCK; ENGINEERING, IDEAL CITY.

CIVITAVECCHIA. This Roman port city located northwest of **Rome** was an important harbor first built under Emperor Trajan, and it later became a papal harbor. In the early 1500s, Pope Julius II commissioned **Donato Bramante** to extend the Fortezza Giulia, now called the Forte Michelangelo, which was completed by **Michelangelo**. By the time Leonardo arrived in Rome in September 1514, with his student **Francesco Melzi**, both Julius II and Bramante had died, and Pope **Leo X**, elected in 1513, gave the commission to Antonio da Sangallo the Younger (1484–1546). Sangallo was Bramante's apprentice and had worked with him on the papal apartments.

Giorgio Vasari described how in October 1515, Leo X visited the port and decided to expand its fortifications, and scholars think Leonardo's architectural designs played an important role in the final project. In Leonardo's ***Codex Atlanticus*** are two pages of drawings for the port. On fol. 63v, Leonardo annotated several small drawings that show a two-story building with steps that lead into the sea. On fol. 271v, Leonardo drew another view of the port next to a sketch of the fort, which was under construction during the same time. Leonardo's general layout was followed in the renovations, and one can assume Leonardo was familiar with Antonio da Sangallo's work, given their shared interest in military **architecture** and water projects, including the building of canals and draining of swamp land around Rome. *See also* BOATS; BRIDGES; WATER STUDIES.

CLARK, KENNETH MACKENZIE (1903–1983). British art historian Kenneth Clark was

trained in the fine arts, and with the help of American connoisseur **Bernard Berenson**, Clark was hired as director of the Ashmolean Museum in Oxford and then at the National Gallery in London, while also holding the position of surveyor of the Royal Collection. He worked with commercial television in London to introduce art to the public through his BBC television series called *Civilisation. A Personal View*, for which he received an honorific knighthood. Clark was interested in French Impressionism and the Gothic Revival, but he primarily studied art of the Italian **Renaissance**.

In 1929, Clark was hired to catalog Leonardo's drawing collection at Windsor Castle in London, and a year later he organized an exhibition of Italian Renaissance painting at the Royal Academy of London, which raised the profile of Italian art in England. Clark was dedicated to renovating the museum space, cleaning and reframing **paintings**, bringing electricity to the museum, and extending opening hours to encourage more museum visits. In 1935, he published his *Catalogue of Drawings of Leonardo da Vinci in the Collection of His Majesty the King at Windsor Castle*, in two volumes, which established a firmer chronology for Leonardo's drawings and remains the standard study today. It was later expanded with additional research by **Carlo Pedretti** into three volumes, published in 1968–1969, and in 1939, Clark published a series of lectures on Leonardo he gave at Yale University in 1936, in a book titled *Leonardo da Vinci: An Account of His Development as an Artist*. The book was revised in 1952, and has been reprinted regularly since then since Clark's interpretation of Leonardo's career remains valid today. This publication established a monographic format dedicated to the study of one artist, which became a standard book type in art history.

During World War II, Clark oversaw the removal of the National Gallery collection offsite, but he kept the museum open for concerts and lectures during the war. Influenced by English art critic John Ruskin (1819–1900), who argued that beauty should be enjoyed by everyone, Clark supported public art collections and argued that private art patronage did not offer enough widespread support for the arts. His work on Leonardo set the standard for how monographs are written today, and his writing remains one of the most balanced and clear discussions of Leonardo's career and art. *See also* KEMP, MARTIN; MUSEUMS; RICHTER, IRMA ANNE; RICHTER, JEAN PAUL.

CLASSICISM. Classicism refers to a set of philosophical ideals and stylistic principles that derive from ancient Greece and **Rome**, the two main cultures from which Western civilization can be traced. Many of these ideas continued after the fall of the Roman Empire and into the Middle Ages, where a resurgent interest in classicism can be seen in the Carolingian and Ottonian eras, while **Renaissance** society witnessed a broader, more comprehensive revival of classicism. Humanist scholars in the Renaissance who focused their studies on classicism were called antiquarians, while today they are called classicists, and contemporary students can major in classics at their university. During the Renaissance, classical antiquity was seen as having laid the foundation for the establishment of Christianity through the prophecies of the ancients, who foretold the coming of Christ; therefore, humanist scholars were interested in reviving the ideas of antiquity, while Renaissance artists carefully studied the art of antiquity to generate a new form of realism by revisiting classical painting, **sculpture**, and **architecture**.

Classical aesthetics in art involve a harmonious balance of proportions where the parts come together to create a cohesive whole. Symmetry and regularity are important components of classical architecture, and buildings must display a clarity of design and solidity of form. Classical elements include columns, triangular pediments, arches, and domes, with stone and marble the favored materials. Classical architecture also displayed superior **engineering**, and architect **Filippo Brunelleschi** traveled to Rome to study the materials and proportions of such ancient buildings as the Pantheon to solve the problem of how to span the diameter of the enormous **Florence** Cathedral dome. In attempting this

feat of engineering, he invented **linear perspective**, which was codified by **Leon Battista Alberti** in his treatise on painting, *De pictura*, from 1435.

Brunelleschi also introduced the classical column order in his Ospedale degli Innocenti (Hospital for Founding Children), built in Florence in about 1419, and he promoted the architectural language of ancient Roman engineer **Marcus Pollio Vitruvius**, whose treatise *De architectura*, from the 1st century BCE, informed many generations of Renaissance architects in their construction methods, building decorations, layouts for different types of buildings, proportions, and aesthetics. Classical architecture was first promoted in Renaissance writings by Alberti in his treatise *De architectura*, from 1450, which was modeled on Vitruvius, and later architects like Andrea Palladio (1508–1580) continued to write architectural treatises that universalized the language of Vitruvius.

In painting, the classical style was expressed in the Renaissance as a form of idealized realism with a similar clarity of design and harmonious balance of figures and objects arranged on the pictorial surface. **Atmospheric perspective**, found in ancient Roman landscape wall murals, was reintroduced in Renaissance painting, while in the 1400s, mathematical perspective was added to the classical techniques of depicting three-dimensional space on a two-dimensional surface. Classical aesthetics in the Renaissance also involved creating a balance between expression and restraint, stability and movement, and the real and the ideal. Artists strove to first study nature and then capture the most beautiful aspects of nature in their paintings to elevate their art from that of a mere copier to that of a pictorial expression of a philosophical ideal.

Meanwhile, civic sculpture became important to the new mercantile class in the Renaissance, and monumental hollow cast bronze sculptures began to reappear in the emerging urban centers as an expression of cultural superiority. The bronze equestrian figure of Marcus Aurelius in Rome, as well as the freestanding marble Apollo Belvedere and Laocoön sculptures in the Vatican, were well known in the Renaissance. The Apollo was discovered in 1483, and belonged to Giuliano della Rovere, who became Pope Julius II, and it was at some point installed in the Belvedere Palace in the Vatican, where artists were able to make sketches of it. The Laocoön depicts the Trojan priest trying to fend off serpents sent down to him and his two sons as punishment from the gods. The story was well known in the Renaissance, and this sculptural group was excavated from a villa at the edge of Rome in 1506, restored, and placed in the Vatican. As soon as Pope Julius II heard about the excavation, he sent **Michelangelo** and **Giuliano da Sangallo** to the site to confirm the identity of the sculpture group.

Humanists like **Marsilio Ficino**, credited with reviving Platonism in Florence in the 1400s, and **Giovanni Pico della Mirandola**, who initiated a discussion of human achievements throughout time in his treatise *Oration on the Dignity of Man*, were central to Leonardo's cultural background, while such later Renaissance scholars as **Baldassare Castiglione**, who outlined the importance of rhetoric and other ancient fields of study for the proper education of the nobility, echoed Leonardo's discourse on the value of studying painting in Renaissance society. *See also* GEOMETRY; HUMANISM; MEDICI; PLATONIC ACADEMY.

CLEVE, JOOS VAN (c. 1485–c. 1540). Sometimes called the "Leonardo of the North," Flemish painter Joos van Cleve worked primarily in Antwerp but traveled to Bruges, France, and perhaps Italy, where he became known for his portraiture. Van Cleve painted in a northern realism influenced by Early **Renaissance** Flemish painter Jan van Eyck (c. 1390–1441), but he also introduced a soft **sfumato** characteristic of Leonardo. He made copies of several of Leonardo's works, perhaps indirectly through Leonardo's students, which include four versions of Leonardo's lost ***Holy Infants Embracing***. Van Cleve could have been introduced to Leonardo's **paintings** in France when he was commissioned to paint **portraits** of **Francis I** and Eleanora of Austria. He was one of many Flemish artists inspired by Leonardo's style. *See also* LEONARDESCHI.

CLOCK. Leonardo's interest in gear mechanisms and automated instruments led to his study of clocks. His ***Madrid Codices*** reveal sketches of a variety of clock mechanisms meant to improve existing clock technology, which, by the 1400s, was already fairly sophisticated. By this time, clockmakers were beginning to use springs instead of weights to power clocks, and they sought better ways to keep the force of the spring even with a chain or gut. Leonardo worked on a spring equalizer to make clocks more reliable, and he also designed an astronomical clock, seen in a drawing of a clock set to Venus and the sun in the ***Paris Manuscript*** L, fol. 92v. He also came up with ideas for an alarm clock, including an instrument that would allow water to trickle into a basin that, once it reached a certain weight, would sink down to release a gear system attached to Leonardo's legs that would raise his feet up in the air. *See also* ASTRONOMY; ENGINEERING; INVENTIONS; WATER STUDIES.

CLOS LUCÉ. The Château of Clos Lucé (originally called Cloux) was Leonardo's final home in France, near the king's summer home, Château d'Amboise. This is where Leonardo spent the last three years of his life, working as the premier painting and engineer and architect of the king, where he was paid 1,000 *ecussoleil* a year in pension. Documents related to Leonardo's work in France are now located in the National Library in Paris. Charles VIII had purchased Amboise in 1490, using it as a summer home, and his nephew, **Francis I**, spent most of his summers there during his youth.

Leonardo was introduced to the French aristocracy after Francis I's cousin, King Louis XII, led his military into Italy and conquered **Milan** in 1500, during the Italian Wars, to become the duke of Milan. In 1506, Leonardo returned to Milan at the request of **Charles II d'Amboise**, the French governor, where he lived until 1513, under the patronage of Louis XII. In 1516, Leonardo was invited to move to France to work for Louis XII and then the newly elevated king, Francis I. He brought all of his belongings, including several unfinished panel **paintings** (most notably the ***Mona Lisa***), his **notebooks**, his two favorite students, and several servants across the mountains and into France. Leonardo, 64 years old at the time, certainly did not intend to return to Italy, and while his career was limited by physical ailments, he settled in Amboise and turned his attention to his notebooks, which he intended to publish before his death

Leonardo's elegant home, Clos Lucé, was linked to the king's palace by an underground walkway that allowed Leonardo to easily entertain important royal guests and artists. During this time, Leonardo theorized an **ideal city** of **Romorantin**, designed a double helix staircase, worked on a canal and swamp drain system around Lyon, and designed several temporary festival stage sets that included **automatons** and other entertainments. In October 1517, Cardinal Luigi of Aragon passed through Amboise on his way to Germany. His retinue of 35 courtiers and servants included his secretary, Antonio de Beatis, who kept a journal of their travels and described their visit with Leonardo on October 10. Here Antonio described three paintings that Leonardo showed his guests, one that is thought to be the *Mona Lisa*, the ***Saint John the Baptist***, and the ***Virgin and Child with Saint Anne***, all of which are now in the Louvre Museum. Antonio mentioned that a portrait of a Florentine woman was commissioned by Giuliano de' **Medici**, but the next day Antonio instead mentioned a portrait of a Lombard woman. It is not clear which description refers to the

Château du Clos Lucé, Amboise, Loire Valley, France. Exterior view.

Mona Lisa, and it suggests that there might be another, now-lost female portrait by Leonardo. Leonardo's country home is now a museum that displays several newly renovated rooms set up as Leonardo's living quarters, workshop, and library, in addition to a garden park that features recreations of some of Leonardo's **inventions**. *See also* MUSEUMS.

CODEX ARUNDEL. The *Codex Arundel* (London, British Library, Arundel 263) is a collection of 285 sheets, or folios, that result in 570 pages of slightly different sizes bound together in a volume named after one of the earliest owners, Thomas Howard, Earl of Arundel, who bought it in Spain. In 1831, the codex was purchased by the British Museum from the Royal Society of London. Since then, a facsimile copy of the book has been made, most recently in 1998, and in 2007, the volume was digitized by the British Library and made available to the online public at http://www.bl.uk/manuscripts/FullDisplay.aspx?ref=Arundel_MS_263. This codex includes discussions primarily on **geometry**, mechanics, and birds in flight done throughout Leonardo's life from about 1478 until 1518. Leonardo likely gathered these writings together to publish them in separate treatises, but later book binders cut the sheets into pages and bound them together out of order.

Carlo Pedretti sought to reconstruct the original chronological order of the manuscripts that make up the *Codex Arundel*, which was published as *Il Codice Arundel 263 nella British Library* (**Florence**, Giunti), 1998. According to Pedretti, the codex consists of about 15 booklets that were originally cataloged as a collection of scientific studies. Indeed, the first 60 pages focus on mechanical studies, but then the codex moves to a section on **optics**, **astronomy**, and geometry, among other subjects, which Leonardo mentions are an extension of earlier observations. The volume is now unbound, and Pedretti's reordering of the sheets brings the oldest sheet, a description of sea monsters, to the front of the volume, followed by Leonardo's studies of **hydraulics** and **architecture**, corresponding to his work for Duke **Lodovico Sforza** in **Milan** in the 1480s.

The next section includes Leonardo's notes taken after leaving Milan in 1499, while he was traveling throughout Italy, before settling back in Florence. The final section of the codex includes studies for works commissioned by **Francis I**, the king of France, where Leonardo notes on the last sheet, dated 1518, his impatience with geometry and the fact that his soup was getting cold (fol. 245r). This is one of Leonardo's last observations as an elderly man, written just before his death. Ultimately, Pedretti sought to group the folios together in thematic and chronological order, although Leonardo himself likely regrouped his folios in different ways while working on them, and he folded the pages differently while carrying them around. This collection of **drawings** and studies are an important part of Leonardo's work, and are similar to the ***Codex Leicester*** in subject matter and form, while second to the ***Codex Atlanticus*** in importance. *See also* ENGINEERING, NOTEBOOKS.

CODEX ASHBURNHAM. This cardboard bound collection of notebook folios and **drawings** from c. 1492 consists of two volumes that were taken out of ***Paris Manuscript*** A (fols. 81–114) and *Paris Manuscript* B (fols. 91–100), located in the Bibliotheque de' l'Institut de France. Book thief Count Guglielmo Libri (1803–1869) cut the folios and stole them from the library while working there cataloging manuscripts. He then sold them to British manuscript collector Bertram, Fourth Earl of Ashburnham (1797–1878), in 1847. After the theft was discovered, Bertram's son returned the folios to Paris in 1890, and they remain there today in these two short volumes separated from their original manuscripts and given the name of their temporary owner. The two codices have a total of 44 folios, with the first volume containing 34 folios of 5.9 x 8.6 inches and the second volume with 10 folios at 6.2 x 9 inches each. The sheets date from between 1487–1490, and consist primarily of sketches of **architecture** and art, while the second volume is dedicated specifically to Leonardo's ideas on painting. *See also* NOTEBOOKS; PAINTINGS; *TREATISE ON PAINTING*.

CODEX ATLANTICUS. This codex is a collection of Leonardo's notes and **drawings** bound together in 12 volumes. The name derives from the large atlas sheets (25.5 x 17.3 in.) the pages were mounted on, of which there are 1 119 sheets of various subjects dating from c. 1478, when Leonardo began his notebook studies in **Florence**, until his death in 1519, in France. After Leonardo's death, his student, **Francesco Melzi**, inherited his books, but after Melzi's death in 1570, his heirs divided and sold the folios and they gradually dispersed into different collections. These particular sheets were gathered together by Italian sculptor Pompeo Leoni (c. 1533–1608), who sold them to the Marquis Galeazzo Arconati, who then donated them to the Biblioteca Ambrosiana in **Milan** in 1637.

It was Leoni who mounted the folios onto large sheets of paper, the size used to make atlases, and he organized them in an aesthetic order rather than chronologically or by subject. In 1968, the codex was restored and bound into 12 volumes following Leoni's order, but more recently they have been unbound so that the sheets can be studied in a more effective way. The drawings range from mathematical studies, **botanical studies**, geography, **architecture**, and mechanics, among other subjects. In one sketch from 1508, Leonardo introduces the first known "octant projection," whereby a sphere is divided into eight equally sized spherical triangles called Reuleaux triangles. Other sketches show designs for a giant **crossbow**, a hoist, Archimedean screws, catapults, a bicycle, a hygrometer, various **cranes**, a **self-propelled cart** that anticipates the automobile, excavators, siege machines, water systems, wings, and so on. *See also* ENGINEERING; GEOMETRY; INVENTIONS; MATHEMATICS; NOTEBOOKS; WATER STUDIES.

CODEX FORSTER. This collection of annotated **drawings** consists of five pocket-sized **notebooks** bound into three volumes (called *Forster* I.1, I.2, II.1, II.2, and III) and located in the Victoria and Albert Museum in London. Dating from 1487–1505, the collection totals 354 sheets, with 101 sheets of two booklets (4 x 5.7 in.) in volume I, 159 sheets in two booklets (2.7 x 3.75 in.) in volume II, and 94 sheets (2.4 x 3.5 in.) in volume III. These notebooks were done in **Milan**, where Leonardo was reported to always carry a pocket-sized notebook attached to his belt where he could describe and draw his observations. The booklets begin with notes on hydraulic **engineering** and the movement of water. Then the sheets provide some notes on **geometry**, perhaps guided by the ideas of mathematician **Luca Pacioli**, who Leonardo met in Milan, followed by more **hydraulic** studies, a *Study of Horses* (Windsor, Royal Library), Leonardo's first anatomical study of a human head, some studies of force and motion, and a few city maps. *Forster* I.1, done in **Florence** in 1505, contains a discussion of **topology**, the mathematical study of the deformation of one shape into another shape to study the properties of space. Topology did not become a branch of **mathematics** until the 20th century, but many scholars have observed its properties as an outgrowth of geometry since antiquity.

Leonardo da Vinci, *Study of Horses*, c. 1490, silverpoint on paper, 9 8 x 7 4 inches, London, Royal Library, Windsor Castle.

The collection is named after English writer John Forster (1812–1876), whose wife donated the drawings to the Victoria and Albert Museum upon Forster's death in 1876. The notebooks originated in an earlier collection gathered together by Pompeo Leoni (c. 1533–1608), which was sold to Count Galeazzo Arconati, who donated the collection to the Biblioteca Ambrosiana in Milan in 1637. The books were perhaps stolen and then sold sometime after 1700, when they later reappeared in the estate of John Forster as part of his vast library of first editions, rare books, journals, and illustrated manuscripts. *See also* ANIMAL STUDIES, SCULPTURE; WATER STUDIES.

CODEX HAMMER. *See CODEX LEICESTER.*

CODEX LEICESTER. This collection of annotated sketches consists of 72 pages of Leonardo's handwritten scientific observations punctuated by small **drawings** throughout the text. The pages are formed from 18 large sheets, folded in half and written on both sides. The unfolded sheets measure 11.8 x 8.6 inches. At one point the codex belonged to Thomas Coke, First Earl of Leicester, and after his death in 1842, the collection was purchased from the Leicester estate by Armand Hammer, who hired Leonardo scholar **Carlo Pedretti** to reassemble the pages into an original order and translate the text into English. During this time, the codex was called the *Codex Hammer.* In 1994, the codex was purchased by Bill Gates for a record sum of more than $30 million, and it is the only Leonardo manuscript held in a private collection. Gates commissioned digital images of the entire manuscript and offers the original manuscript periodically for public exhibitions.

Like Leonardo's other codices, this one was assembled from a diverse set of writings on **hydraulics**, water, **astronomy**, and **geology**, and although it was bound together into a book, the pages have now been unbound. Topics range from the movement of water to a discussion of how the moon reflects **light**, which Leonardo theorized as reflecting the sun's light off water on its surface. This idea defined the first theory of planet shine a century before Johannes Kepler (1571–1630) proved how it works. Finally, several pages are devoted to Leonardo's explanation of the fact that fossils are found on mountains because mountains were originally part of the sea before being lifted upward, which is a theory that went against the traditional biblical flood narrative and instead anticipated modern studies of plate tectonics. *See also* NOTEBOOKS; WATER STUDIES.

CODEX MADRID. *See MADRID CODICES.*

CODEX ON THE FLIGHT OF BIRDS. While most of Leonardo's codices include a diverse collection of notes and **drawings** on a variety of subjects gathered together in a group of volumes that lack an overarching order, his *Codice sul volo degli uccelli* (*Codex on the Flight of Birds*) is the sole volume exclusively devoted to one subject—the flight of birds. Here Leonardo wrote extensively and drew more than 500 sketches on mechanical **flying machines** and the movement of air and bird flight patterns. This codex, completed in about 1505–1506, consists of 18 folios, 8.2 x 6 inches, bound together and located in the Biblioteca Reale in Turin. It was originally part of the ***Paris Manuscripts*** that were stolen by Count Guglielmo Libri from the Institut de France.

In this work Leonardo began with a study of birds in flight, and then he theorized several flying machines, including an ornithopter with flapping wings and a **helicopter** with rotating wings. Although none of Leonardo's studies were successful in their application despite testing models in the hills around **Florence** and off buildings in **Milan**, his ideas offered remarkably accurate observations of balance, gravity, velocity, and movement, which influenced future aeronautical studies. He wrote about the speed of falling objects and how density relates to weight, while he wondered why ice floats on water even though it is denser. His observations of how wings compress air and the influence of wind on movement were central to his flight studies. Throughout the early part of the codex, Leonardo appears

to be most interested in the study of gravity, which he defines as one object's attraction to another, and he describes how gravitational motion pulls two objects together in a straight line. His studies of gravity include objects of different shapes and how they balance if they are set at different angles.

Leonardo then applied these studies on gravity and balance to his observations of bird **anatomy** and movement. He carefully described the bone structure of bird wings and observed how when a wing is raised, the bones are the highest part, but when the wing is lowered, the feathers are the highest part, while the heaviest part of the bird guides its movement. Then, when a bird changes direction while moving, its wings will bank left and right as the body tilts, much like a boat in water. By observing how a bird can raise and lower its body, and move in the direction of wind like a kite, Leonardo was able to intuit an understanding of air pressure. Then, he began to discuss tailwind and how a bird can right itself from a fall. Next, Leonardo shifted his discussion to mechanical flying machines and suggested which strong organic materials could be used to build a mechanical bird, noting that metals should be avoided due to the possibility of fracturing or breaking. His flying machines included a bat-like ornithopter, a screw-driven **helicopter**, a linen **parachute**, and a flying platform.

Leonardo's lifelong interest in birds in flight is found in many other drawings interspersed throughout his **notebooks**. His student, **Francesco Melzi**, inherited this codex upon the artist's death, and in 1637, it was donated to the Biblioteca Ambrosiana in Milan. In 1797, Napoleon took several of Leonardo's codices to Paris, where some folios were stolen, only to resurface in London. The codex was then reunited and returned to Italy, and the first English translation dates to 1893. The Wright brothers knew the work and credited Leonardo for their achievements. *See also* ANIMAL STUDIES, INVENTIONS.

CODEX TRIVULZIANUS. The *Codex Trivulzianus*, sometimes called the *Milan Codex*, was a collection of 62 sheets, of which 55 sheets remain, bound together in a volume now located in the Biblioteca Trivulziana in the Castello Sforzesco in **Milan**. The sheets measure 8 x 5.5 inches, and the varied subjects date to 1485–1490, making it one of Leonardo's oldest codices, with its date range confirmed by his description of a solar eclipse he witnessed in Milan in March 1485 (fol. 8r) and his designs for the *tiburio* of **Milan Cathedral**, which date to the summer of 1487. In one sketch, Leonardo made rough outlines of a dome on an octagonal drum, clearly based on **Filippo Brunelleschi's** solution for the Florence Cathedral.

The cathedral in Milan was begun in 1386, by Archbishop Antonio da Saluzzo, under the patronage of Gian Galeazzo Visconti in the late Rayonnant Gothic style, which was designed by French and German architects. Work slowed down after the death of Galeazzo in 1402, but by 1452, three-quarters of the nave and side aisles had been completed under the patronage of Francesco Sforza. Numerous architects worked on the crossing and the dome through the late 1400s during the rule of **Lodovico Sforza**, although construction was interrupted by the French invasion of Milan in 1499. The octagonal dome was finally completed by 1510, under the direction of French governor **Charles II d'Amboise**, who had befriended Leonardo during his time in Milan and consulted him on various projects in the city.

The notebook primarily includes sketches of religious and military **architecture**, and notes on Leonardo's literary education, including word lists. Throughout Leonardo's life, he sought to improve his education, and he also owned a small library. His word lists were formed from technical terms, **Latin** books, and specialized literary words found in his readings. In some cases, his word lists, done in mirror writing to accommodate his left-hand script, are superimposed over various sketches, including **caricature** heads. An English translation of the notebook was first published in 1971, and a facsimile edition was published in 1980. *See also* NOTEBOOKS.

CODEX URBINAS. *See TREATISE ON PAINTING.*

CODEX WINDSOR. *See WINDSOR FOLIOS.*

CODICES OF THE INSTITUT DE FRANCE. *See PARIS MANUSCRIPTS.*

COLOR. Leonardo is known for his restricted color palette, where he favored shading and shadowing over bright colors. While his early works are consistent with the colors of his teacher, **Andrea del Verrocchio**, his later palette, seen most famously in his ***Mona Lisa***, was primarily formed from combinations of whites, browns, yellows, greens, gray-blues, and reds. In his unpublished ***Treatise on Painting***, Leonardo proposed a new theory of color based on his understanding of how the eye perceives color. Aristotle had developed the first color wheel, with four colors related to the four elements of fire, wind, earth, and water, while Leonardo listed six colors: yellow (earth), green (water), blue (air), and red (fire), in addition to white and black, which were previously not considered "true" colors but white was described as the base upon which to receive color, and black was the lack of color.

For Leonardo, white could be used to show **light** and black to show dark, which was essential to the shading and shadowing needed to model figures in a realistic three-dimensional form. Furthermore, Leonardo also understood that there are discrepancies in how color is perceived; for example, in **atmospheric perspective**, distant mountains are perceived in a hazy, slate-blue color, in contrast to how they appear when viewed from close range. The scientific study of color did not begin until Isaac Newton's work in 1666, where he used a prism to define a fuller spectrum of colors, while Leonardo's understanding of color anticipated these later advances. *See also* CHIAROSCURO; FRESCO; OIL; SFUMATO; TEMPERA.

COLOSSUS. *See* SCULPTURE.

CONFRATERNITY OF SAINT LUKE. The Confraternity of Saint Luke anticipated the development of a painter's guild in **Florence** in the 1400s. Guilds were associations of professional workers that emerged in the Middle Ages, and they functioned to codify the professions of craftsmen and merchants by overseeing apprenticeships, prices, and contracts by negotiating legal issues and advocating for the profession in local politics, while also networking and promoting the field more broadly. Many guilds became powerful by the 1300s, when the middle class was beginning to emerge and guild leaders were elected to office. They controlled the economy and were important in the collection of taxes. By the 1400s, guilds had also become important art patrons.

In Florence, there were 12 major and middle guilds, called *Arti*, including the major guilds of judges and notaries, wool and silk merchants, doctors, and bankers. First nine and then 14 minor guilds (*arti minori*) were also established, which included such artisans as leather workers and ironworkers. Many guilds were dedicated to a patron saint, and Saint Luke was the common name for these painter's organizations since Luke, one of the four Evangelists, is thought to have painted the only known portrait of the Virgin Mary from life.

Early on, the guild represented house painters, manuscript painters, and panel painters since guilds were formed around the use of similar materials rather than function and style. Similarly, sculptors who worked in marble were in the stone and wood carvers guild, while bronze casters were in the goldsmiths guild. This also explains why painters were initially in the guild of doctors and pharmacists, called the *Arti dei Medici e Speziali*, since they bought their **colors** at the same markets as the pharmacists, and pigments were often also herbal remedies and spices. A Confraternity of Saint Luke was first established in the mid 1300s, and it grew into an established guild later in the 1500s. When Leonardo completed his apprenticeship with **Andrea del Verrocchio**, he joined the Confraternity of Saint Luke in 1472. *See also* FRESCO; OIL; PAINTINGS; RENAISSANCE; SCULPTURE, TEMPERA; VERROCCHIO, ANDREA DEL.

CONTI, BERNARDINO DE' (1470–1523). Bernardino de' Conti was a northern Italian

painter who worked in the style of Leonardo and became known for his highly realistic half-length profile **portraits** set against a dark background. Little is known of Conti's early life, but he was born into the noble family of the counts of Castelseprio outside Varese, Lombardy, and studied painting in Pavia before meeting Leonardo in **Milan** in the mid-1490s, while working in the Sforza court. His *Madonna and Child with the Infant Saint John the Baptist*, c. 1496, is an **oil** on poplar panel painting in the Brera Art Gallery in Milan, inspired by Leonardo's *Madonna of the Rocks* in the pose and hand gesture of the Virgin and the rocky, cave-like background.

An exceptional *Profile Portrait of a Young Woman* (London, private collection), which has alternatively been attributed to **Giovanni Ambrogio de Predis**, **Bernardino Luini**, and **Giovanni Antonio Boltraffio**, reveals the difficulties of attribution among this circle of **Leonardeschi** students and followers. Here we see a young woman with her face in profile but her torso angled very slightly toward the viewer to show her intricately gold-threaded dress, with sleeves tied on by delicate ribbons that allow her white undertunic to bunch out. The woman wears her hair tied back in a scarf in the fashion of aristocratic Milanese women, and she wears a headpiece across her forehead similar to Leonardo's ***Belle Ferronnière***, while Leonardo's ***Bella Principessa*** reveals the same hairstyle and careful modeling of the nose, lips, and chin. *See also* SFORZA, LODOVICO.

CONVEYORS. *See* ENGINEERING; WATER STUDIES.

COPERNICUS, NICOLAUS (1473–1543). Like Leonardo, the younger Polish scientist Nicolaus Copernicus was a **polymath**, most interested in math and **astronomy**. He is best known for his promotion of the heliocentric idea that the planets revolve around the sun, a heretical notion during his time. While Copernicus published his findings in *De revolutionibus orbium coelestium* in 1543, just before his death, Leonardo's **notebooks** were not published until much later, although his sketches were available for consultation in the collection of his student, **Francesco Melzi**, who brought them back to **Milan** after Leonardo's death. Leonardo's annotations reveal his own startling astrological observations that the Earth is like a star and his anti-Aristotelian observations of the moon, while he also wrote that the Earth is not in the center of the sun's orbit: "Il sole no si muove." Leonardo made several pen-and-ink sketches of the moon's surface in his ***Codex Atlanticus***, fol. 310r and 674 v, and in his ***Codex Leicester***, fol. 1r, he sought to measure the sizes of the Earth and moon in relation to the sun. Ancient Greek astronomer Aristarchus of Samos had already intuited a sun-centered universe, which Copernicus confirmed mathematically.

Indeed some scholars have suggested that Leonardo may have invented heliocentrism, although he never described the concept with specificity but instead wrote various observations that alluded to such things as the invention of the telescope. Leonardo was interested in mirrors and other optical devices, and he described in his ***Paris Manuscript*** F the concept of the telescope through his studies of the magnification that occurs with eyeglasses. He also included a sketch that some scholars consider a prototype for a telescope. These ideas would have been widely discussed at the time, and Copernicus would not have worked in isolation on his transformative theories. Indeed, Leonardo's observations would certainly have been central to bridging the gap between observed theory and mathematical proof, as offered in Copernicus' work. *See also* CLASSICISM, GALILEI, GALILEO; MATHEMATICS; RENAISSANCE.

CORVINUS, MATTHIAS (1443–1490). Documents show that in 1485, Leonardo was commissioned by Matthias Corvinus to paint a Madonna and Child panel, a contract negotiated either by **Lodovico Sforza** since Leonardo was working in **Milan** at the time or through Lorenzo de' **Medici**, Leonardo's patron in **Florence**. Although this work was likely never begun, perhaps it would have been similar to the Madonna and Child known as the ***Virgin of the Rocks***, which Leonardo was working on at

the time, to be completed with side panels by **Giovanni Ambrogio de Predis** and his brother Evangelista.

Corvinus was king of Hungary and Croatia, as well as king of Bohemia and duke of Austria. While he solidified his territories through warfare, but was also a patron of art and science, and established one of the largest libraries, called the Bibliotheca Corviniana, in Europe, while he sought to establish a humanist **Renaissance** culture similar to that in Florence. His marriage to Beatrice of Naples, the daughter of King Ferdinand I of Aragon, provided him a further link to **humanism**, and during a visit to Florence, **Marsilio Ficino** introduced him to Plato's ideas on kingship. *See also* CLASSICISM.

CRANES. Leonardo's practical tools related to civil **engineering** also include cranes, which were meant to save labor and time through heavy lifting and moving. **Filippo Brunelleschi** had already invented an elevated crane, as well as his more famous reversible hoist, which allowed builders to avoid having to reverse the oxen in the traditional ox-driven hoist system used to transport building materials to the domes and roofs of tall buildings. Indeed, Brunelleschi's many technological **inventions** would certainly have been a direct influence on Leonardo's lifelong interest in civil and mechanical engineering. In fact, while a student in the shop of **Andrea del Verrocchio**, Leonardo would have witnessed the completion of the lantern of the Florence Cathedral dome with a copper ball designed by Verrocchio, which was hoisted up to the top of the lantern in 1472.

In his **notebooks**, Leonardo made sketches of two different automatic release mechanisms for cranes so that when the load reached the ground, the carrying hooks released. Leonardo noted that a weighted hook was problematic because the weight mechanism could hit the side of the load and jam. A version of his double crane, similar to a bucket wheel excavator, is found in the ***Codex Atlanticus***, fols. 3r and 4r, where workmen can fill buckets that move up and down on the same rope, acting as a counterbalance. This type of crane could be used to dig out a canal and would allow the load to be released more quickly, and then the crane would swing around to rise up and meet its next load, while a second crane was already carrying down a second load. A sketch in the Royal Collection, ***Windsor Folios***, fol. 12348v, shows the double winch crane attached to a circular trolley, which can move to unload dirt in different directions. While these were large cranes likely used at a marble quarry, Leonardo also designed smaller cranes that could be transported on a wheeled platform, cranes that could move horizontally, and cranes that could pivot. *See also* ARCHITECTURE.

CRANKSHAFTS. *See* ENGINEERING.

CREDI, LORENZO DI (c. 1459–1537). Florentine painter Lorenzo di Credi began working in the shop of **Andrea del Verrocchio** in about 1480, a year before Leonardo left for **Milan**, and after Verrocchio's death, Credi inherited his workshop. His *Portrait of a Young Woman*, c. 1490 (New York, Metropolitan Museum of Art), is an **oil**-on-wood panel painting that depicts a half-length portrait of a woman standing in a landscape wearing a black dress and folding her hands in front of her. A translucent veil covers and reveals her hair, showing a heightened realism, with an **atmospheric perspective** background. He was perhaps influenced by Pietro Perugino (c. 1446–1523), who also trained with Verrocchio, and is known for his elegant, linear style. His portrait of Lorenzo di Credi shows the artist as a serious, young man (1488, Washington, D.C., National Gallery of Art) in a similar style. Leonardo's early portraits were similar to Credi's, and they certainly influenced one another, as well as the early portraits of **Raphael**. Many scholars think the three quarter pose and face of Credi's *Portrait of Caterina Sforza* resembles the composition of Leonardo's ***Mona Lisa***. *See also DREYFUS MADONNA*; DÜRER, ALBRECHT, *MADONNA OF THE CARNATION*; PORTRAITS.

CROSSBOW. One of Leonardo's better-known **inventions** is his giant crossbow, which may not have provided much practical value in warfare, but it was intended to impress the

enemy with its massive size. Thus, Leonardo was not only interested in the applied value of his military **engineering**, but also he understood the psychological impact of war. A detailed drawing of his crossbow appears in the *Codex Atlanticus*, fols. 143r, 149r, 153r, and 155r, from about 1500, where Leonardo gives its measurements as 42 *braccia*, or 27 yards wide. The bow was transported on six wheels, made of a flexible wood, and designed to hurl large stones. A crank would be turned to draw the bow back to a pin, which would lock the bow in place while it was loaded. Then a soldier would use a mallet to knock away the pin, which would release the bow. Crossbows began to supersede hand bows in Europe in the 1100s, but they remained logistically difficult to carry and load, so hand bows were still favored for close combat, while crossbows were used to propel arrows or rocks a farther distance. By the early 1500s, gunpowder weapons had begun to be used in warfare, and although they were initially less accurate and slower to use than hand bows, they soon replaced hand bows and crossbows. *See also* NOTEBOOKS, RENAISSANCE.

D

DAVINCIITE. Davinciite is a transparent, dark lavender rock-forming silicate mineral discovered in the mountains of the Kola Peninsula in Russia and first classified in 2011. Its brittle, vitreous material has a hardness of five on the Mohs scale, and it is a complex mineral characterized by geometrical irregularities similar to those favored by Leonardo in his geological sketches. For this reason, this rare mineral was named after Leonardo. *See also* GEOLOGY; NOTEBOOKS.

DISSECTIONS. *See* ANATOMY.

DISTILLER. *See* CHEMISTRY.

DIVING SUIT. Leonardo's lifelong interest in water led him to devise **bridges**, **submarines**, dykes, hydraulic pumps, and other **inventions** that allowed people to travel over water, through water, and under water, as well as to divert and store water. While in **Venice** in 1500, he was hired by the Republic of Venice to create military equipment for water battle, and in this setting Leonardo theorized the first scuba diving suit that would allow a combatant to swim unnoticed to an enemy boat and breach its hull to sink it. The concept of underwater battle existed in antiquity, when men were described as swimming underwater while either holding their breath or using a plant stem as a snorkel.

Herodotus (c. 484–c. 425 BCE) described a naval battle where a Greek military hero named Scyllis was taken prisoner aboard the ship of Persian king Xerxes I but jumped overboard with a knife to cut the flotilla of ships loose from their moorings while breathing through a hollow reed before swimming nine miles back to shore. Aristotle also spoke of the use of diving bells, while in the Middle Ages goggles were later made of tortoiseshells and diving suits described in the first illustrated military technology manual, written by German engineer Konrad Kyeser (1366–1405), called *Bellifortis*, which although it was not printed until much later, was known throughout Germany in the **Renaissance** through copies of excepts.

Later in the 1400s, Leonardo was first to mention the use of air tanks in his ***Codex Atlanticus*** and explored various options for breathing underwater. Leonardo's diving suit would have been made of leather and included a face mask, with tubes made of cane that led upward and were attached to cork bells above the water. In an illustration in his ***Codex Arundel***, fol. 24v, Leonardo specifically shows the breathing instrument with a balloon that could be inflated to keep the diver above water and deflated so the diver could sink underwater, and the cane tubes are encased in metal rings to keep them from being crushed. This theoretical model was never used, but the first functional leather diving suits were introduced in England in about 1710, to facilitate underwater salvage work. *See also* BOATS, DOUBLE HULL; ENGINEERING; WATER STUDIES.

DONATELLO (c. 1386–1466). Donato di Niccolò di Betto Bardi, known as Donatello, was a Florentine goldsmith and sculptor in the first

half of the 1400s. His father was a wool carder, and Donatello began his training in about 1400, as a stone carver working on the Cathedral of **Florence**. Donatello traveled to **Rome** with his friend **Filippo Brunelleschi** after Brunelleschi lost the 1401 competition for the bronze doors of the Florence Baptistery to **Lorenzo Ghiberti**, and in Rome they worked in the thriving antiquities market. After returning to Florence a few years later, Donatello entered Ghiberti's workshop after he met Ghiberti at the cathedral complex while Ghiberti was working on the bronze doors in the first years of the 1400s. Ghiberti was the leading goldsmith in Florence in the first half of the 1400s, and he maintained a large workshop and foundry. Donatello also continued to develop his stone masonry techniques into figural sculpture, revealing a classical style that influenced **Michelangelo's** later work in marble carving.

Donatello's earliest marble sculpture was the seated *Saint John the Evangelist*, carved in 1409–1411, for a niche on the façade of the Florence Cathedral (now in the Museo dell' Opera del Duomo, Florence), which shows his early drapery studies and naturalistic pose and proportions. Donatello was also interested in **perspective**, which he translated from the pictorial surface to low relief carving, as seen in his *Feast of Herod* bronze relief panel, made in about 1427, for a baptismal font in the Cathedral of Siena. Ghiberti oversaw the project beginning in 1416, which included six bronze reliefs set into the sides of a hexagonal basin. The panel completed by Donatello depicts a scene of John the Baptist's head being presented to Herod at a dinner party, while Salome dances. Here Donatello shows the space divided into the foreground, mid-ground, and background in a mathematical codification where orthogonal lines converge into a central void to heighten the emotional impact of the scene. Ghiberti's discussion of **optics** in the third volume of his *Commentari* explains the importance he gave to perspective in art, which would have formed the training Donatello received in his workshop.

Donatello's bronze *David* commissioned in about 1430, by Cosimo de' **Medici** (Florence, Bargello Museum) for the courtyard of the Medici Palace, is the first freestanding nude figure since antiquity. Donatello was interested in ancient art, and he worked to seek a harmonious balance between realism and idealism in his graceful figures. In 1443, he was hired by the family of famous mercenary soldier Erasmo da Narni to cast a bronze equestrian monument commemorating his military achievements. It was placed on a tall pedestal in front of the Basilica of Saint Anthony in Padua. Here we see the soldier, seated erect on the back of his horse, wearing his armor and holding a staff. His horse appears to stride forward as one front leg lifts up in a contrapposto stance, which Donatello learned from ancient sculptural examples. This front leg rests on a cannonball to provide adequate support for this heavy, hollow cast bronze, while the tail juts out to counterbalance the weight bearing down on the front legs. Large hollow bronze casting, a technique revived from antiquity, was tremendously complex given the weight and expense of the materials, as well as the high, controlled heat needed to work with molten bronze. These figures were typically cast in several pieces, soldered together, and filed and treated with wax and other ingredients to create a smooth patina finish, a process Donatello would have mastered in Ghiberti's workshop. This was also the first equestrian monument since antiquity and therefore was important to **Andrea del Verrocchio**, who cast a similar monument later in the century in **Venice**.

Leonardo's lifelong interest in equestrian figures began with his anatomical studies of horses in battle and ended with his failed attempts to create a colossal horse cast in one piece. Leonardo also sought to shift the weight of the bronze off the front so the horse could rear up on its back legs, a feat of engineering that was never accomplished in Leonardo's lifetime. Donatello's perspective studies were also part of the broader studies of pictorial space that defined Florentine art of the first half of the 1400s, studies Leonardo continued with his own optical experiments at the end of the century. Like Donatello, Leonardo also looked closely at nature in the development of his increasingly realistic works, where the

human body began to move in space in a more accurate visual presentation. Donatello died when Leonardo was 14 years old, just before Leonardo entered the workshop of Verrocchio. Verrocchio was at the high point of his career during this time, and Leonardo's training in his studio was largely informed by the earlier sculptural innovations of both Ghiberti and Donatello. *See also* ANATOMY, ANIMAL STUDIES, CLASSICISM; RENAISSANCE.

DOUBLE HULL. In the 1490s, Leonardo experimented with a double hull boat, found sketched in Manuscript B of the ***Paris Manuscripts***, fol. 11r. Here he designed a double layer to a boat hull to provide additional structural support and block the entry of water from damage to the hull caused by attacks or wrecks, where a diver could perforate the wooden hull from underwater by separating its planks or ram the hull with an attack vessel. He wrote next to the drawing, which was one of three nautical images on this page, that the sketch depicts the "motion of the void of ships," which alludes to the way the double hull could provide flexibility by allowing some shifting between the two shells to alleviate any shearing or cracks. *See also* BOATS; DIVING SUIT, ENGINEERING; SUBMARINE, WATER STUDIES.

DOUBLE WINCH CRANE. *See* CRANES; ENGINEERING, INVENTIONS

DRAGON SHIELD. *See* MEDUSA SHIELD.

DRAWINGS. While only about 20 **paintings** by Leonardo are known, it is thought that he made almost 100,000 drawings, which is an average of five sketches a day during his career. Leonardo is known to have carried pocket-sized **notebooks** with him to record his daily observations, and about 6,000 notebook sheets exist today, many with several sketches on both front and back. These drawings include preliminary sketches for paintings, studies for **sculpture** and **architecture**, mechanical devices, **engineering** and **botanical** and **animal studies**, human **anatomy** and the proportions and movement of the body, **landscapes**, and maps.

Leonardo used pen and ink; red, white, and black chalks, watercolors; and metal-point on different sizes of parchment that were either bound in **notebooks** or individual sheets that were sometimes folded or reused later. Artists had access to more paper in the 1400s as more paper mills were established in Italy, with sophisticated production techniques that allowed for less pulpy, higher-quality parchment. Prior to this time, paper was imported from the east and was expensive; therefore, more explorations and studies were done in the **Renaissance**, where diverse projects might appear on both sides of a sheet of paper, making a chronological assessment of an artist's drawings nearly impossible.

Full-scale drawings, called cartoons, were also routinely done for a projected work, and although many of those studies do not exist today, Leonardo's ***Virgin and Child with Saint Anne and Saint John the Baptist*** (*Burlington House Cartoon*) is an excellent example of this type of drawing. Here we see that instead of crosshatching Leonardo drew in a sophisticated technique of shading, and since he was left-handed, he shaded from bottom left to top right. Leonardo's destroyed ***Battle of Anghiari*** cartoon was also instrumental in providing such later artists as Peter Paul Rubens (1577–1640) a visual document of Leonardo's unfinished mural, while wall drawings may also exist under the plaster of the council room in the Palazzo Vecchio in **Florence**. Leonardo's drawing process can also be seen in his unfinished panels, including his ***Adoration of the Magi***, while new technological advances have allowed scientists to see preliminary sketches done beneath the pigment of Leonardo's finished paintings. His drawing style, with its heightened realism of shading, shadowing, and depth, ultimately allowed Leonardo to document in a visually accurate way his many scientific observations and theoretical ideas. *See also* CARICATURES; CARTOGRAPHY; *CODEX ARUNDEL*; *CODEX ASHBURNHAM*; *CODEX ATLANTICUS*; *CODEX FORSTER*; *CODEX LEICESTER*; *CODEX ON THE FLIGHT OF BIRDS*; *CODEX TRIVULZIANUS*; *MADRID CODICES*; MILAN, *PARIS MANUSCRIPTS*; *TREATISE ON PAINTING*; *WINDSOR FOLIOS*.

DREYFUS MADONNA. This painting, also called the *Madonna and Child with the Pomegranate*, is an **oil** on poplar panel in the National Gallery of Art in Washington, D.C., that is currently attributed to Florentine painter **Lorenzo di Credi**, a student who worked in the shop of **Andrea del Verrocchio** during the same time as Leonardo. This small panel measures 6.5 x 5.25 inches; is dated c. 1475–1480; and is named after English collector Gustave Dreyfus (1837–1914), who purchased the painting in Paris. His heirs sold the painting to the Duveen brothers, who sold it to the Samuel H. Kress Foundation in New York in 1951. The foundation then donated the painting to the National Gallery in Washington, D.C., in 1952.

It was common for workshop students to paint in the style of their teacher, which explains why Leonardo's early work shares a stylistic affinity to Verrocchio's paintings, and it also illuminates the similarities between Leonardo's early work and that of other contemporary students in Verrocchio's shop. Because of this, the *Dreyfus Madonna* has alternatively been attributed to Leonardo and dated to about 1469, which would make it his first independent painting, although this attribution is not universally accepted.

Here we see a half-length Virgin seated in a dark room lit by two windows, one on either side of her head, that reveal gently sloped hills beyond a row of fields. The Christ Child stands on the Virgin's lap, striding forward on his left leg while looking and reaching up toward his mother. She gazes down at her son while offering him a small pomegranate that is broken open to reveal its inner red seeds. The fruit has many meanings, including righteousness, knowledge, or wisdom. These Madonna and Child **paintings** were popular in **Florence** in the late 1400s and early 1500s, and many were made for small chapels and private homes. Several of these early compositions influenced the next generation of Madonna and Child paintings, including the famous High **Renaissance** versions done by **Raphael** in Florence in the early 1500s. *See also* CATHOLICISM; LEONARDESCHI.

DÜRER, ALBRECHT (1471–1528). German artist Albrecht Dürer was a painter, printmaker, and scholar interested in **mathematics**, **perspective**, **optics**, and proportions. He is considered Leonardo's counterpart in Northern Europe. Durer traveled to Italy, where he likely met Leonardo, and he is credited with introducing classical ideas into Northern **Renaissance** art. During his first visit to Italy in 1494–1495, he made landscape sketches while crossing the Alps and then settled in **Venice**, where he was influenced by classical aesthetics related to the human body and its proportions. During Dürer's second trip to Italy in 1505–1507, he stayed again in Venice, where he painted religious works for German merchants living there. It was likely during this visit that he met **Luca Pacioli**, perhaps in Bologna, and Dürer could have also met Leonardo through either Pacioli or Florentine artist **Lorenzo di Credi**, who worked in the shop of **Andrea del Verrocchio** at the same time as Leonardo and traveled to Venice with Verrocchio.

While we do not know definitively whether Dürer met Leonardo in person, he certainly was familiar with Leonardo's drawings, evident in his copies of several of Leonardo's anatomical and animal drawings, while some of Dürer's notes also seem to recall parts of Leonardo's ***Treatise on Painting***. It was perhaps in Bologna where Dürer learned mathematical perspective from Pacioli, while he also learned to shade his figures in the manner of Leonardo. His painting *Christ among the Doctors*, from 1506 (Madrid, Museo Thyseen-Bornemisza), shows a new composition where the figures fill the entire frame and one figure standing to Christ's left is shown in caricature, which could have been influenced by Leonardo's studies of the grotesque. *See also* CARICATURES; CLASSICISM; HUMANISM; LANDSCAPES; POLYMATH.

DYKES. *See* CANAL LOCK.

E

EARTHSHINE. *See* ASTRONOMY.

EASTLAKE, ELIZABETH (1809–1893). Art historian and critic Lady Elizabeth Eastlake was the first woman to write a regular art column for the *Quarterly Review*, published in London beginning in the early 1800s. She was both an artist and writer who traveled extensively in her youth and learned German while living there from 1827–1829, to recover from an illness. She married Sir Charles Eastlake, director of the National Gallery in London, at the age of 40, and together they traveled throughout Europe, purchasing art for the museum collection. During that time, she developed an interest in Italian **Renaissance** art. She is credited with translating German art historian **Gustav Friedrich Waagen's** publications into English, which introduced German art history into England. Her two-volume book *Five Great Painters*, published in 1883, included chapters on Leonardo, **Michelangelo**, Titian, **Raphael**, and **Albrecht Dürer**, and was an important contribution to English scholarship that helped to promote the importance of these particular artists in English language art history. *See also* BERENSON, BERNARD; BODE, WILHELM VON, FREY, KARL OTTO, LIPHART, KARL EDUARD VON; MCCURDY, EDWARD ALEXANDER COLES; MORELLI, GIOVANNI; MUSEUMS RICHTER, JEAN PAUL.

ENGINEERING. Leonardo's scientific interests were both theoretical and practical. Yet, the majority of his studies were in engineering, and most of his mechanical **inventions** were designed to service architectural and infrastructure construction and military equipment. He had planned to write a treatise called *Elements of Machines*, but it was never completed, and upon his death his **notebooks** were dispersed into many different collections. Leonardo's notebooks show many engineering sketches and include such inventions as the **canal lock**, rotating **bridge**, various water pumps, a bucket-and-wheel excavator, different types of scaffolds and **cranes**, and military equipment, all of which he illustrated throughout his career. While many of Leonardo's ideas and inventions anticipated numerous scientific achievements made in subsequent centuries, he did not work in isolation, but his technical innovations were built on the advances made in antiquity, in the Islamic world, throughout the Middle Ages, and into the Early **Renaissance**.

The Renaissance engineer most influential on Leonardo was perhaps **Filippo Brunelleschi**, a goldsmith and architect who worked in **Florence** and was a generation older than Leonardo. Brunelleschi built the dome of the Florence Cathedral, where he invented a reversible hoist and other tools needed to span the diameter of the drum with what was hoped to be the largest dome since antiquity. Leonardo took Brunelleschi's practical ideas further to develop a unifying theory that he called the "elements of machines." He understood that machines are made of a finite number of parts that could be interchanged to create new types of machines, and this theory was in keeping with his same ideas about a finite number of

shapes and movements in nature. Leonardo planned to write a treatise on machines, and before he died he categorized them into different types of basic mechanisms, for example, screws, levers, wheels, axles, hinges, hooks, springs, chains, and pulley systems, which could be used together in various ways to generate movement. He also thought of the human body as a type of machine, and many of his engineering studies were done in comparison to the movement of the human body.

Some of Leonardo's mechanical designs include various crankshaft systems in the ***Madrid Codices*** I, fol. 86r, which employ longer shafts than previous designs, which he discovered facilitated their movement, and on fol. 29v, he sketched a small crankshaft used to wind thread onto a bobbin, and on fol. 28v, he drew a crankshaft that moves with a toothed wheel and worm screw. With these studies, it is clear that Leonardo took a basic concept and sought to apply it to many different kinds of needs, each time with a simplicity of design and economy of parts. In this final example, Leonardo wrote that this design was superior because the motion was smooth and the design compact. Many of Leonardo's designs were never actually used but have since been tested out, with varied success rates. Clearly, some were ideas Leonardo sought to experiment with before introducing a working model. His sketches gained accuracy throughout time, but given that his notebooks are not arranged in chronological order, his learning curve is difficult to reconstruct.

After the wheel, the crank is considered one of the most important mechanical devices in history, and a crank-connecting rod system that allowed for a continuously rotating machine was first introduced by Islamic scientist and inventor Al Jazari (1136–1206), from Turkey, in his treatise *The Book of Knowledge of Ingenious Mechanical Devices*, which includes descriptions of more than 100 machines, including wheeled machines with gears, camshafts and crankshafts, and various types of clocks. While many of his machines had practical applications in moving water and soil for construction, he also designed several automata, including a water flushing mechanism to be used after washing hands and a musical robot. His mechanical peacock perhaps inspired Leonardo's robotic knight, lion, and dragonfly, among other automata found in Leonardo's notebooks. Al-Jazari's treatise would have been introduced into Renaissance Italy via Moorish Spain, and it was only one example of the many medieval Islamic technological advances that laid the foundation for Italian Renaissance engineering practices.

Leonardo's civil engineering studies included designs for **bridges** and canals. His double winch crane (***Windsor Folios***, fol. 12348v) and his lift and conveyor (*Madrid Codices* II, fols. 154v and r) show improvements to existing machines, taking into account Leonardo's interest in water, which he described as the "conveyor of nature," and these machines helped form Leonardo's ideas on the infrastructure needed in an **ideal city**. Leonardo's designs for new types of furnaces were in the service of chemical engineering, while his mechanical automata were eventually supplanted by electrical robots with the modern development of electrical engineering. Ultimately, Leonardo found many parallels between the human body and mechanical designs, and he considered the human body a type of machine. His goal was to generate scientific solutions to the practical problems of human creation through the manipulation of the natural environment, and these goals remain the same for engineers today. *See also* ANATOMY, ARCHITECTURE, AUTOMATON; BIOMECHANICS; CHEMISTRY, MUSIC; WATER STUDIES.

EQUESTRIAN MONUMENTS. *See* DONATELLO, SCULPTURE, VERROCCHIO, ANDREA DEL.

ESTE, ISABELLA D'. *See* MANTUA, *PORTRAIT OF ISABELLA D'ESTE*; PORTRAITS.

F

FICINO, MARSILIO (1433–1499). Florentine **Renaissance** humanist scholar Marsilio Ficino played an important role in the introduction of Platonic ideas into Florentine culture in the 1400s. Born in a small town outside **Florence** to a physician who worked for Cosimo de' **Medici**, Ficino entered the household of the Medici at a young age and was educated along with the Medici children to become a member of their intellectual circle. He first studied with John Argyropoulos (c. 1415–1487), who immigrated to Italy after the Fall of Constantinople in 1453, when an influx of Greek scholars into Italy spurred the introduction of ancient Greek philosophical thought, which until then had been accessible solely through ancient Roman sources. In this way, these Greek scholars aided in the introduction of **classicism** and **humanism**, the hallmarks of a Renaissance education.

Ficino went on to tutor the next generation of Medici children in classical philosophy and was director of the **Platonic Academy** in Florence, established by Cosimo de' Medici in 1462, to revive the ancient Greek Academy, founded in Athens by Plato (c. 428–c. 348 BCE), as the first school of higher learning in the Western world. Plato, together with his teacher, Socrates, and his most famous student, Aristotle, laid the foundation for Western philosophy and science. For this reason, Cosimo sent book buyers throughout Europe and into the east to build a collection of manuscripts that formed the basis for his life's work in translating Plato's texts from Greek to **Latin**. It was Ficino who characterized the era in which he lived as a golden age, when **light** was restored to the liberal arts. He also wrote several books on medicine and astrology, and defined the notion of Platonic love in his book *De amore*, which he sought to align with his homosexual desires. Furthermore, Ficino was a lifelong vegetarian, and some scholars have argued that Leonardo was a vegetarian as well. It was ultimately Ficino's teachings that fueled intellectual thought in Renaissance Florence and helped shape Leonardo's ideas on natural philosophy, or the philosophy of nature, which was pivotal to his life's work in bringing together art and science. *See also* HOMOSEXUALITY; MIRANDOLIA, GIOVANNI PICO DELLA; POLIZIANO, ANGELO; VEGETARIANISM.

FILARETE, ANTONIO DI PIETRO AVERLINO (c. 1400–c. 1469). Antonio di Pietro Averlino, known as Filarete, was a Florentine goldsmith who studied **sculpture** with **Lorenzo Ghiberti** and then moved to **Rome** and then **Venice** before settling in **Milan** to work for Duke Francesco Sforza upon the recommendation of Cosimo de' **Medici**. There, he worked as an architectural engineer for the Sforza family before returning to Rome, where he died in about 1469. Leonardo would certainly have heard of Filarete, a generation older than him, while studying in **Florence**, and when he followed Filarete's footsteps to Milan, he would have been introduced to Filarete's classica **architecture**.

In Milan, Filarete introduced the "all'antica" architectural style to this late medieval city with his plans for the Ospedale Maggiore, begun in 1456, for Francesco Sforza. This large

building, now part of the University of Milan, was the first **Renaissance** building in the city. The ground plan of the hospital was a cross set within a square that followed a rational plan inspired by **Filippo Brunelleschi**, who worked in Florence in the 1420s, during the same time Filarete was studying with Ghiberti. The hospital was originally planned as a large rectangle with four internal courtyards, but Filarete's design was not completed, and when he left Milan in 1465, the building was finished by two local architects who worked in a Lombard Gothic style, which explains why the exterior features a classically arched arcade inset with Gothic bifurcated windows. While in Milan, Filarete also renovated the Castello Sforzesco to transform it from a medieval feudal castle into a Renaissance palazzo, but he is best known for his 25-volume architectural treatise written in Milan between 1460–1464, called the *Libro architettonico.* This treatise includes some of Filarete's original plans for the hospital, but it primarily includes his plans for the **ideal city** of *Sforzinda.* This theoretical city layout features an eight-pointed star surrounded by a circular moat and canals that ran parallel to the streets and were connected to the river.

The manuscript was widely copied during the late 1400s, and the best-preserved copy was dedicated to Piero de' Medici and is now in the Biblioteca Nazionale Centrale in Florence. It was his idea for an efficient infrastructure, a classical design, and rational plans, which inspired Leonardo in his ideal city plans and canal designs done in Milan and at **Romorantin**. In Leonardo's ideal plan for Milan, he included a **canal lock** to protect the city from flooding and added broader streets, and he noted (in ***Paris Manuscript*** B, fols. 36–47) that the city should be kept clean for the purposes of hygiene. He had witnessed a particularly serious outbreak of the plague in Milan in 1484, and he argued that such illnesses were the result of poor sanitation. Although neither Filarete nor Leonardo's ideal plans for Milan were realized, both were instrumental in subsequent urban planning. *See also* ALBERTI, LEON BATTISTA; ARCHITECTURE, CLASSICISM; ENGINEERING; MARTINI, FRANCESCO DI GIORGIO.

FILELFO, FRANCESCO (1398–1481). Italian **Renaissance** scholar Francesco Filelfo worked in **Milan** during the same time as Leonardo and is thought to be a third cousin. He first studied the humanities curriculum in Padua and was at a young age asked to teach in **Venice.** From there, he received an appointment to work as a notary in Constantinople in 1420, which was a major trade center for the Republic of Venice. This appointment allowed him to learn Greek under the direction of John Chrysoloras, who is credited with helping introduce the Greek language in Italy during the Renaissance. Three years later, Filelfo traveled to Hungary to work for Byzantine emperor John VIII Palaeologus, where he amassed a large collection of ancient Greek manuscripts. He returned to Venice in 1427, but moved to **Florence** soon thereafter, staying there a short time before angering Cosimo de' **Medici,** at which point he accepted an offer to teach in Siena before accepting another offer, this time to teach in Milan in 1440, for Duke Filippo Maria Visconti. From there he spent the rest of his career as an itinerate scholar, writing and lecturing throughout Italy, while also writing poems, panegyrics, funeral orations, and other ceremonial prose for the royal court.

In 1450, Filelfo began his most famous work, the *Sforziad*, written to commemorate the new Milanese leadership under the Sforza family. He made one final trip to **Rome** in 1475, before returning to Milan, and then again to Florence to work for Lorenzo de' Medici in 1481. Filelfo's many career changes are considered to be the result of a difficult personality, as he frequently angered his patrons. By this time, however, he was in his early 80s and lived for only two weeks in Florence before dying of dysentery. In 1482, Leonardo followed in Filelfo's footsteps with an invitation to work for Duke **Lodovico Sforza** in Milan, where he described himself as an engineer who could also paint. In Milan, Leonardo was also given the task of devising stage sets and performance venues for royal ceremonies, and he certainly would have been introduced to the *Sforziad*, which was still used for official events.

An interesting connection between Filelfo and Leonardo emerged recently with the

discovery of a portrait done in chalk and ink on vellum thought to have come from one of four surviving illuminated copies of Filelfo's *Sforziad*. This copy of the book, a 1490 printed edition found in the National Library in Warsaw, was beautifully illustrated by hand and signed by Milanese artist Giovanni Pietro da Birago. Art historian **Martin Kemp** has suggested that the drawing, originally attributed to an unknown 19th-century German artist, was actually done by Leonardo and depicts Bianca Giovanna Sforza (d. 1496), the illegitimate daughter of Lodovico Sforza. The drawing would have been inserted into the printed book and given to her and her husband, Caleazzo da Sanseverino, as a gift, perhaps at their marriage in 1489. Galeazzo was a courtier in the circle of Lodovico Sforza, and Bianca was his second cousin. He also befriended Leonardo, and documents show Leonardo was a guest in his house in Milan, which is perhaps when Leonardo made the drawing. The drawing was, at some point, removed from the book, only to resurface at an art auction in New York City in 1998. Kemp's book *La Bella Principessa. The Story of the New Masterpiece by Leonardo da Vinci*, London, 2010, details the events surrounding the attribution of this work to Leonardo. *See also BELLA PRINCIPESSA*; PORTRAITS.

FLORENCE. Florence was a thriving city in the 1400s, where merchants, artisans, and scholars worked together to create a city dedicated to the arts and learning. After recovering from the plague in the mid-1300s and successfully defending the city from attacks by **Milan** and Naples in the first decades of the 1400s, the city grew from about 60,000 people to a population of about 100,000 by Leonardo's era, and the *popolo* established one of the earliest proto-democracies in Europe, with power shared among the wealthy bankers, primarily the **Medici** family. The city had more than 20 guilds, which established a prosperous economy of trade and manufacture, and came to be known for its banking industry. Despite continued power struggles throughout the century, Florence became the epicenter for the study of art, literature, classics, philosophy, and science.

When Leonardo was 14 years old, his father arranged an apprenticeship for him in the prominent studio of **Andrea del Verrocchio** in Florence, where Leonardo spent seven years drawing, painting, studying **anatomy**, and pursuing other scientific interests. In addition to his applied training in Verrocchio's workshop, Leonardo was introduced to the humanist ideas prevalent in Florence in the 1400s. The Medici family funded this quest for knowledge by sending book buyers throughout Europe and into the east to build a collection of manuscripts and maps that introduced Florentines to new ways of thinking about the world. Florentines acknowledged they were living in a "new **Rome**," or a "golden age."

In 1482, Lorenzo de' Medici sent Leonardo to Milan to help negotiate peace with his rival, Duke **Lodovico Sforza**, and Leonardo ended up staying in Milan for the next two decades, only returning to Florence after the French invasion of Milan in 1499. When he returned to Florence in 1500, however, the city was completely different. The Medici family had been driven into exile, and Dominican priest **Girolamo Savonarola** had just been executed in 1498, leaving the government in the hands of **Piero Soderini**, who was elevated from his role as prior of the city to the *gonfaloniere*, or head of the Republic, a position he held until the Medici returned in 1512. In 1503, Leonardo reestablished his membership in the Guild of St. Luke in Florence, and Soderini commissioned him for work at the Palazzo Vecchio, but Leonardo returned to Milan in 1506, leaving much of his Florentine work incomplete. During the ensuing years, he returned to Florence for brief time periods, mainly to attend to family matters.

In the first half of the 1400s **Lorenzo Ghiberti** had completed the bronze doors of the Baptistery with the newly introduced **linear perspective**. **Filippo Brunelleschi** had finished the dome of the Florence Cathedral using new techniques of construction. Michelozzo di Bartolomeo (1396–1472) had built the large Palazzo Medici on Via Largo in a newly introduced palace format and style, and **Donatello** had reintroduced the bronze-cast nude male figure from antiquity, while the exterior wall

niches of Orsanmichele were filled with **sculptures** that revealed the emerging realist style blended with classical idealism. **Masaccio** applied Brunelleschi's studies of **perspective** to his **frescoes**, and he re-introduced **atmospheric perspective** from antiquity. **Leon Battista Alberti** wrote three treatises on the arts, which introduced a theoretical framework for the study of the visual arts, while humanist scholars **Marsilio Ficino** and **Giovanni Pico della Mirandola** guided intellectual discourse with their studies of Plato and the notion that Florentines were enjoying a "golden age." These incredible achievements formed the visual and intellectual backdrop for Leonardo's early education in Florence. While most of Leonardo's creative output took place in Milan, the intellectual culture of Florence, where he interacted with other artists, humanists, and scientists, provided him with the notion that humans can work together to achieve universal knowledge. *See also* CLASSICISM; CONFRATERNITY OF SAINT LUKE; HUMANISM; RENAISSANCE.

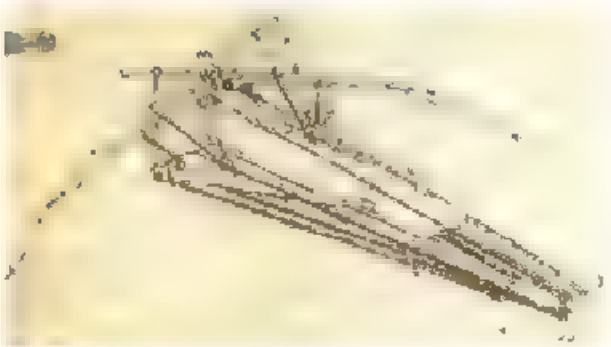
FLUID MECHANICS. *See* HYDRODYNAMICS; HYDROSTATICS; WATER STUDIES.

FLY WHEEL. *See* ENGINEERING; WHEELLOCK MUSKET.

FLYING BICYCLE. *See* FLYING MACHINES.

FLYING MACHINES. Leonardo had a lifelong interest in flying, and through his careful observation of birds in flight and the **anatomy** of birds, he invented numerous mechanical and human-propelled prototypes for flying, including the ornithopter, the aerial screw **helicopter**, various types of mechanical wings, and gliders and **parachutes**, as well as a mechanical dragonfly (***Codex Atlanticus***, fol. 1051v), mechanical bat (*Codex Atlanticus*, fol. 93r), and mechanical eagle (***Paris Manuscript*** B, fols. 73v, 74 v, and r, 75r). It is thought that Leonardo's first invention was a flying machine. His most famous flying machine appears in a drawing entitled *Design for a Flying Machine*, c. 1488 (*Paris Manuscript*, Institut de France, Paris), which shows a wooden frame that supports a prone human body. Attached to the frame are the ribs for a set of wings, likely made in a thick canvas.

Leonardo also theorized a flying bicycle, found in the *Codex Atlanticus*, fol. 897r. Here we see two variations on a design where one driver sits on a machine that resembles a modern bicycle, which did not actually exist in Leonardo's era. The mechanism needed to make the wings flap is unclear, as this was clearly an early design by Leonardo that was not functional, but in this design is a small bell with a knocker inside that dangles on a string in front of the rider to provide an artificial horizon, which is called an attitude indicator, whereby the knocker would hit the bell if the flying machine was tilted or turned. This is perhaps the first example of such an instrument. Leonardo attempted several practice flights from the hills surrounding **Florence** and the roof of a building in **Milan**, but none were successful. Nonetheless, of all of Leonardo's ideas and **inventions**, his interest in flying was perhaps his most enduring fascination. *See also* AERODYNAMICS; ANIMAL STUDIES, AUTOMATON; *CODEX ON THE FLIGHT OF BIRDS*; NOTEBOOKS.



Leonardo da Vinci, *Design for a Flying Machine*, c. 1488, ink on parchment, Paris, Institut de France.

FORTIFICATIONS. *See* ARCHITECTURE.

FRANCIS I (1494–1547). Francis I assumed the crown of France in 1515, upon the death of his cousin, Louis XII, and he ruled until his death in 1547. During his reign, Francis I sought to modernize the aristocratic culture in France, and he worked to establish an intellectual court

modeled on those in Italy. He invited Italian artists to his court, beginning with Leonardo, who introduced many scientific and artistic ideas to France, while Italian artists of the next generation brought the late **Renaissance** style of Mannerism to the Château de Chambord. King Louis XII had initially invited Leonardo to France in 1515, and once Leonardo's patron, Giuliano de **Medici**, died in 1516, he accepted the offer from the newly crowned Francis I to move to Amboise. Leonardo crossed the Alps with his students, **Francesco Melzi** and **Salai**; one servant, and all of his possessions, including the ***Mona Lisa***. Francis I's art collection formed the original collection of the Louvre Museum in Paris, which features the *Mona Lisa*.

Leonardo spent his final years in the Loire Valley at the Château du **Clos Lucé**, located outside the medieval town of Amboise along the Loire River. The Château d'Amboise is just outside of town, while the larger Château de Chenonceau is 10 miles away. The Amboise was taken over by the royal Valois family in the 1400s, becoming a favorite home of the royal family, who hired Italian architects to renovate parts of the Gothic castle into a classicizing Renaissance style. Amboise then became known as the first building in France to use the latest Italianate style. Leonardo was 64 years old when he arrived in Amboise, and Francis I gave him the nearby summer manor home of Clos Lucé (called Cloux), which was connected to the king's castle by an underground walkway, where Leonardo spent the last years of his life. Leonardo died there in 1519, surrounded by his students and household workers, and legends tell us that Francis I visited Leonardo on his death bed.

During his years in France, Leonardo was the king's first painter, architect, and engineer. In his three years there, Leonardo began to organize his **notebooks** into publications, a task left unfinished upon his death. Francis I considered Leonardo not only a great artist, but also a great philosopher, and while the king commissioned various projects, for example, a plan for hydraulic town planning, an ideal urban plan in nearby **Romorantin**, and stage sets and mechanica. objects for royal events, the king primarily enjoyed engaging Leonardo in discussion. Many royal events took place in the Clos Lucé, parts of which were renovated in the Italian style.

Later artists, intrigued by the close friendship between a king and an artist, romanticized their relationship as one of equals and depicted scenes of Leonardo's death in the arms of the king. A painting by François-Guillaume Ménageot shows this subject in a painting, which was shown in the 1781 Salon exhibition (now located in Amboise, in the Musée de l'Hotel de Ville) and repeated in 1818, by Jean-Auguste-Dominique Ingres (Paris, Petit Palais). The younger Italian artist Benvenuto Cellini, who worked for Francis I later in the century, noted that the king considered Leonardo one of the most intelligent men he had ever met, while **Giorgio Vasari** described Leonardo's death in the arms of the king, perhaps from a description provided by Leonardo's student, Melzi, who was present at Leonardo's death on 2 May 1519. After Leonardo's death, his students returned to Italy, where Melzi spent many years organizing Leonardo's notebooks for publication. *See also* LEONARDESCHI, MUSEUMS; PAINTINGS OF LEONARDO.

FRESCO. Fresco painting is a technique that originated in antiquity but was perfected in Italy in the 1300s, with the creation of a superior pigment bond in wall painting. Fresco, which means "fresh" in Italian, refers to the use of water-based pigments applied to a freshly applied, still-damp plaster wall, where the pigments soak into the porous, lime-based plaster, called intonaco, as the plaster dries therefore, the pigments do not lie on the surface of the wall, where they would peel, but rather they are absorbed to create a permanent bond with the plaster. Leonardo's teacher, **Andrea del Verrocchio**, was a versatile artist who worked in panel painting and metal work but not fresco painting. Nonetheless, Leonardo received several wall mural commissions, where he sought to modify the fresco technique with the inclusion of **oil** paint to achieve his characteristic **chiaroscuro** style.

Most of Leonardo's panel **paintings** were done with a mixture of oil and **tempera** on wood, but his attempts to transfer these pigments to wall painting were unsuccessful since oil applied to a damp wall will not dry fast enough and therefore

drip, while oil applied to a dry wall (called a secco) will not soak into the plaster to create a permanent bond. This contributed to the flaking colors of the ***Last Supper***, where the pigments lay on the surface of the intonaco, and his unsuccessful ***Battle of Anghiari*** mural in the Sala dei Cinquecento in Palazzo Vecchio in **Florence**, where Leonardo had to hang braziers to heat the dripping paint. While Leonardo completed the *Last Supper* mural, he eventually abandoned the *Battle of Anghiari* when he returned to **Milan**. *See also* CLASSICISM; COLOR; MICHELANGELO BUONARROTI; RENAISSANCE.

FREUD, SIGMUND (1856–1939). Sigmund Freud received his doctorate in medicine from the University of Vienna and went on to establish a method of psychoanalysis used to treat mental illness. In this method, the psychiatrist seeks to unveil subconscious motivations for maladaptive behavior, and through insight learned while in therapy, the patient can correct this behavior. Freud also introduced the ideas of free association and transference, as well as the notion that sexuality is present in infant behavior, not just in the adult years. According to Freud, through dream analysis, repressed subconscious or unconscious hopes and fears can be brought into a conscious awareness and discussed in what came to be called the "talking cure." Freud's work remains enormously influential despite its decreased use as a therapeutic model.

In 1910, Freud wrote an essay theorizing how Leonardo's childhood experiences manifested in his painting style and homosexual tendencies. The first edition, *Eine Kindheitserinnerung des Leonardo da Vinci* (*A Childhood Reminiscence of Leonardo da Vinci*), was later translated into English as *Leonardo da Vinci and a Memory of His Childhood*. This study is an excellent example of how incorrect interpretations of an artist and his work can emerge when meaning is extrapolated and loose interpretations are created from scant documentation of life events set outside a cultural context. Freud argued that Leonardo's description of being attacked by a vulture, or bird, in his crib, found in the ***Codex Atlanticus***, led him to **homosexuality**, and his interest in Madonna and Child **paintings** was motivated by his illegitimate birth. Later theorists discredited Freud's interpretations but acknowledged his interest in studying Leonardo's personal motivations for his art and science. Meyer Schapiro, in "Leonardo and Freud. An Art-Historical Study," *Journal of the History of Ideas* 17, no. 2 (April 1956): 147–78, states that although Freud knew his ideas were methodologically risky given that they were based on uncertain assumptions, he thought future studies could refine his psychoanalytic approach. Indeed, Schapiro acknowledged that Freud posed important questions about Leonardo's life and artistic motivations, questions that remain unanswered today. *See also* FLORENCE; RENAISSANCE.

FREY, KARL OTTO (1857–1917). A specialist in Florentine **Renaissance** art, Karl Otto Frey studied at the University of Berlin and focused his research on **Giorgio Vasari** and **Michelangelo**. In 1892, he wrote an edited version of the **Anonimo Gaddiano**, also called the *Magliabechiano*. This publication is titled *Il Codice magliabechiano, cl. xvii. 17, contenente Notizie sopra l'arte degli antichi e quella de' Fiorentini da Cimabue a Michelangelo Buonarroti, scritte da Anonimo Fiorentino* (Berlin: G. Grote'sche Verlagsbuchhandlung, 1892. Frey also published the manuscript of Antonio Billi from the same era in **Florence**, and then he published an edition of Vasari's *Vite*.

Many of these earliest art historians spent their careers combing the archives throughout Europe to reconstruct art careers and attributions. This was foundational work, and these archival studies remain the underpinnings from which current scholars base their ideas today. Publications like this one have provided scholars access to the source material needed to confirm attributions for Leonardo's **paintings** and their dates and identifications, from which more recent scholars have been able to create a framework for a better understanding of Leonardo's art career. *See also* BERENSON, BERNARD; LIPHART, KARL EDUARD VON; MCCURDY, EDWARD ALEXANDER COLES; MORELLI, GIOVANNI; RICHTER, JEAN PAUL; WAAGEN, GUSTAV FRIEDRICH.

FURNACE. *See* CHEMISTRY, INVENTIONS.

G

GALILEI, GALILEO (1564–1642). Galileo Galilei was born in Pisa at the end of the **Renaissance** into a family of musicians. His training as a musician provided him with an understanding of mathematical ratios and musical harmonies, in addition to the observation of how pitch changes with the length and vibration of instrumental strings. Since antiquity, **music** was considered a branch of physics, and rhythmic structures were known to reflect the measure of time, while musical harmonies could tell us about the world around us, and they could also be used to reveal astronomical phenomena through the music of the spheres. Like Leonardo, Galileo understood that numbers were the source of everything, and he built upon many of Leonardo's observations in his own scientific studies.

Galileo was also a **polymath**, and he is best known for his studies of speed and velocity, gravity, and free fall. He also invented and improved many scientific tools, for example, the thermoscope and various compasses. He is also known for his support of the heliocentric idea that the planets revolve around the sun, a heretical notion during his time. This idea was first introduced by **Nicolaus Copernicus** (1473–1543), an astronomer and mathematician slightly younger than Leonardo. While Copernicus published his findings in *De revolutionibus orbium coelestium* in 1543, Leonardo observed in his **notebooks** that the Earth is not in the center of the universe, nor in the center of the sun's orbit, which suggests that Leonardo was aware of the concept of heliocentrism. This idea, first mentioned in antiquity, gained traction when Copernicus proved it mathematically. Galileo built on these observations with a telescope, which he used to see the satellites of Jupiter and the rings of Saturn. Galileo learned from Leonardo how to be both an applied scientist and an artist, and he understood that drawing skills were an important tool in visualizing things observed in the sky. In his sketches of the moon, he used shading and shadowing to accurately describe the moon's surface *See also* ASTRONOMY; CLASSICISM; GEOMETRY; MATHEMATICS.

GALLERANI, CECILIA. *See LADY WITH AN ERMINE.*

GEOLOGY. Leonardo da Vinci was influenced by his late medieval predecessors' interest in the natural world, and he took their studies of nature a step further with his detailed **drawings** of plants and rock formations. He was not only interested in the realistic depiction of nature in his **paintings**, but also he sought a scientific understanding of the physical world through detailed observation. Through his studies, Leonardo was one of the first scientists to understand that fossils were the petrified organisms and that their study could help people better understand ecological changes throughout time. When he found seashells in the mountains, he concluded that they were brought there through the natural movement of the Earth's crust, not the Great Flood described in the Bible. He observed that rain waters rush down a mountain and carry rocks and sediment downward, not upward, while a

worldwide flood would have had no place for water to recede, leaving shells in tight layers. He understood that the earth changes throughout time, as water erodes rocks and moves sediment, shifting mountains and adjusting the landscape, which anticipated modern ideas on plate tectonics. He recognized that, like the human body, parts of the earth work together to create a natural harmony.

Leonardo's ***Arno Valley Landscape***, from 1473 (**Florence**, Uffiz. Gallery), shows a distant landscape that unfolds with mathematical **perspective** from the top of a mountain. Leonardo would have been standing at some point outside Florence, in the Apennine Mountains, which extend down the middle of the Italic Peninsula like a spine, while the Arno River passes through Florence and Arezzo before emptying in the Tyrrhenian Sea on the west coast. This landscape view does not show any figures, but instead Leonardo tells the story of the land by depicting its contours in such a way that suggests he is observing geological deposits called turbidites, where sediment settles into layered bedding that shows traces of ripple marks from water current. These geological observations would certainly have risen from Leonardo's study of water currents where he would have seen how larger rocks require more water velocity to move them along than smaller rocks, which can be pushed along by friction in slower moving waters. He wrote in the ***Codex Leicester***, "That thing will be the lightest, the further it be brought by the rivers from the place from which their waters took it; and so the heaviest will be the one carried for the least distance from the place where it split off" (fols. 6A–31v).

Furthermore, low currents have a lower level of erosion, while faster currents have a higher turbidity, which suggests a greater degree of erosion in the rock and pebble beds beneath the water, forming silt in the water and affecting its density. Leonardo's ***Virgin of the Rocks*** (Paris, Louvre Museum) depicts the Virgin kneeling on the ground surrounded by an angel, the Christ Child, and the infant John the Baptist. Behind her is an imaginary cave with both stalactites and stalagmites, which frame a distant mountain view. Leonardo painted the *Virgin of the Rocks* while in **Milan**, where he became interested in the taller, craggy cliffs of the Alps in northern Lombardy. He mentioned in his **notebooks** that he climbed Monte Rosa and spent time walking in the mountains and exploring caves. The setting of this painting has also been described as a grotto that features weathered sandstone banded by the igneous rock diabase to suggest erosion via wind. The foreground vegetation is a further clue to the setting, where Leonardo did not select his plants based on symbolism alone, as previous artists often did, but they provide clues to the location of the work through an understanding of growth patterns.

Leonardo's *Codex Leicester* includes the most detailed paleontological studies made, primarily in Tuscany, while his geological studies were done throughout Italy. **Ichnology** is an area of research focused on the geological features made by living organisms, for instance, dinosaur footprints. Leonardo was interested in the movement of objects and creatures in nature, and he intuited that living organisms left behind the geological patterns he saw all around him. On fol. 28v of the *Codex Leicester*, Leonardo also explains that the heat burning inside the Earth warms the water encased in large underground caverns, and when the water evaporates, it rises to the surface as steam and travels up into the mountains, where it becomes cold. This cold temperature then turns the steam back into water, which forms streams that run down the mountains into rivers. Sometimes, however, the water does not rise up and cool but bursts forth in a "great tumult" to create a violent earthquake or volcano that consumes its own power. *See also* CARTOGRAPHY; HYDRAULICS; HYDRODYNAMICS; HYDROSTATICS, LANDSCAPES; MATHEMATICS; WATER STUDIES

GEOMETRY. Geometry is a field of **mathematics** specific to space and spatial relations, and it is the branch of mathematics most studied by **Renaissance** artists and architects, one of whom was Leonardo. During this time, geometry and arithmetic were the two major branches of math. Euclid of Alexandria (300s–200s BCE) is considered the

founder of geometry. He worked as a mathematician in Alexandria, a large coastal city in Egypt that was part of the Hellenistic Greek Empire under Ptolemaic rule, and maintained one of the largest libraries in the ancient world. Euclid's *Elements* is one of the most influential treatises of mathematics in the world, consisting of 13 books that cover plane and solid geometry, while he established a deductive method that laid the foundation for modern logic and the scientific method. Euclid's book was one of the first treatises to be published in Western Europe with the establishment of the printing press in the mid-1400s, second to the Bible, and it was a cornerstone of the medieval university curriculum, which first consisted of grammar, logic, and rhetoric, followed by arithmetic, geometry, **music**, and **astronomy**, which were needed for the study of philosophy and theology.

His treatise brought together the work of earlier Greek mathematicians, notably Pythagoras (c. 570–495 BCE), who is credited with the Pythagorean theorem and a cohesive description of the five regular solids (the tetrahedron, cube, octahedron, dodecahedron, and icosahedron), both of which influenced Leonardo's work. Pythagoras also devised a mathematical system of tuning stringed instruments, which was enormously influential in the Renaissance, and ideas on the harmony of the spheres, whereby the planets move with a mathematical precision similar to mathematical proportions, thereby creating an inaudible harmony of the universe. This idea influenced not only Renaissance humanists, but also scientists in their quest to better understand the movement of the planets. His ideas were known in the Renaissance through the writings of Plato, whose *Timaeus* discusses the nature of the physical world.

Meanwhile, algebra, which was originally a form of geometric algebra in Ancient Greece during the time of Plato, emerged as a separate field of study in the writings of medieval Persian mathematician Muhammad ibn Musā al-Khwārizmī (c. 780–850) in his *Compendious Book on Calculation by Completion and Balancing*, while Indian mathematician Brahmagupta (c. 598–c. 668) first established the use of zero as both a number and placeholder, as well as negative numbers, in his astrological treatise *Brāhmasphuṭasiddhānta*. This text was first translated into Arabic, which influenced Al-Khwārizmī, whose own treatise was eventually translated into Latin and called *Algorithmi de numero indorum*. By the 1200s, many Islamic treatises were known in the West, influencing the ideas of Leonardo Bonacci, known as Fibonacci (c. 1175–c. 1250), a medieval mathematician from Pisa whose father was a wealthy merchant. As a young boy, Fibonacci traveled Northern Africa, where his father traded with the Almohad Caliphate in Algeria, who also held the territory of Al-Andalus, or Islamic Iberia, just before the fall of the Moorish Empire in Spain to Christians in the mid-1200s.

This era was a time of rich exchange between east and west, and Fibonacci's contact with Indo-Arabic scholars is reflected in his treatise *Liber Abaci*, from 1202, which established the Arabic numeral system in the Western world, with the numbers zero to nine and place values, which used an abacus for calculations. His primary interest was a practical system of bookkeeping needed for international merchants and included methods of calculating interest rates and weights and measures. This book was fundamental to the more sophisticated accounting methods that emerged in the Renaissance, but Fibonacci is best known for introducing his theoretical numerical sequence, first noted in India in the 500s, where each number is the sum of the previous two numbers, which shows exponential growth patterns. Fibonacci also wrote a treatise on geometry in 1220, called *Practica Geometriae*, primarily used for surveying, a measuring technique increasingly used by artists like Leonardo to create maps, as well as military inventions and water diversion projects.

Many of these mathematical writings were brought to medieval Europe via trade routes established with the east in the 900s and 1000s, and Latin translations of this Arabic and Greek material began in the 1100s, during the same time as the establishment of universities and an increase in scholasticism

in the West. During the Renaissance, artists embraced geometry to devise practical solutions for their craft, specifically the more sophisticated **engineering** models needed in the creation of large architectural spaces and the mathematical establishment of a realistic pictorial space in painting, therefore, Renaissance artists were primarily interested in geometry, **perspective**, and **optics** in their establishment of a more technically sophisticated art. Yet, many of them, including Leonardo, developed an interest in geometry and other mathematics that superseded what was needed for their craft, and in this way, artists increasingly began to also be seen as scientists who carefully observed the world around them. *See also* ADDING MACHINE; ALBERTI, LEON BATTISTA; ARCHITECTURE; BRUNELLESCHI, FILIPPO; CARDANO, FAZIO, CARDANO, GIROLAMO, CARTOGRAPHY, CLASSICISM; ENGINEERING, FICINO, MARSILIO; HYDRAULICS, INVENTIONS, NOTEBOOKS; PACIOLI, LUCA; PIERO DELLA FRANCESCA.

GHIBERTI, LORENZO (1378–1455). Florentine goldsmith Lorenzo di Bartolo Ghiberti died at the age of 77, three years after Leonardo was born. Leonardo would have been familiar with Ghiberti's two sets of bronze doors on the **Florence** Baptistery, made during the time **Filippo Brunelleschi** was completing the dome of the Florence Cathedral, **Masaccio** was painting the **frescoes** with the newest advances in **linear perspective** and **atmospheric perspective**, and **Donatello** had just cast the first freestanding nude figure since antiquity. Ghiberti was also a historian who promoted humanist ideas and wrote a treatise on art called the *Commentari* (*The Commentaries*), which included the first known artist autobiography. He also introduced one of the earliest self-portraits, seen in a small medallion head located on the Gates of Paradise at the Florence Baptistery, proclaiming his artistry at a time when individual artists were beginning to position themselves in higher society.

Ghiberti was born in a small town outside Florence and was first trained by his father, who was a goldsmith, before moving to Florence to study in the workshop of a lesser-known artist named Bartoluccio di Michele. In 1401, when he was 23 years old, Ghiberti won a competition to complete a set of bronze doors for the Florence Baptistery, which took more than 20 years to complete, at which point Ghiberti received a commission in 1425, to complete the final set of doors, which took 27 years. During this time, Ghiberti oversaw a large foundry that employed many of the best-known sculptors of the next generation, including Donatello, Paolo Uccello (1397–1475), and **Antonio del Pollaiuolo**, all of whom were interested in **perspective**. Ghiberti was familiar with Arab scientist Alhazen's *Book of Optics* from the 11th century, which had just been translated into Italian in the late 1300s and called *Deli Aspecti*. Ghiberti quoted extensively from this book in the third book of his *Commentari*, in a section on **mathematics**, and this chapter was fundamental to the Florentine development of mathematical perspective, as well as the interest in **optics** among so many artists, notably Leonardo.

Like Leonardo's **notebooks**, Ghiberti's comments on art resulted from a collection of manuscript pages that were scattered after his death and reorganized and recopied into three chapters in the mid-1400s. The first chapter focuses on ancient art, the second on modern art, and the third on perspective and optical studies. Perhaps Ghiberti never meant for these studies to be gathered together in this way, since the first two chapters are historical and the third chapter is a practical, mathematical discussion. These studies nonetheless reflect a shift in the profession of art and the status of artists in the **Renaissance**, when artists were viewed as not just manual laborers, but also men of ideas and intellectual pursuits. Like his contemporary, **Leon Battista Alberti**, Ghiberti considered the importance of antiquity and nature in art, but he also argued for a balance between theory and practice. He emphasized the study of **anatomy**, astrology, and the natural sciences, which were consistent with Leonardo's emphasis on the scientific basis of art. Leonardo likely knew of Ghiberti's *Commentari*, as Ghiberti's ideas grew out of the same rich cultural context where Leonardo studied. Indeed, **Giorgio Vasari** was aware

of Ghiberti's writings, which he consulted in writing his own *Vite* in the 1500s, in which he further promoted the notion that artists are creative individuals, with a skill set that may even be divinely inspired. *See also* CLASSICISM; HUMANISM.

GHIRLANDAIO, DOMENICO (1448–1494). Florentine painter Domenico Ghirlandaio was a few years older than Leonardo, and they both worked together in the studio of **Andrea del Verrocchio**. Ghirlandaio first studied with his father, a goldsmith known for his metal garlands, popular among Florentine women at the time, and then he apprenticed with Alesso Baldovinetti (1425–1499), from whom he learned the **fresco** technique. Ghirlandaio is best known for his **frescoes**, and he trained **Michelangelo** in this wall-painting method. In 1481, Ghirlandaio was called to **Rome** to paint two frescoes on the Sistine Chapel walls, including his *Vocation of the Apostles*, which shows Peter and Andrew called upon by Jesus in front of a lake, and *Resurrection of Christ*, which is now lost. Ghirlandaio often painted contemporary noblemen in his frescoes, including members of the Tornabuoni family, who was director of the Rome banking branch of the **Medici** family.

Back in **Florence** in 1483, Ghirlandaio would have seen **Hugo van der Goes's** *Portinari Altarpiece*, that was commissioned by Tommaso Portinari, who oversaw the Medici branch bank in Bruges. The large triptych altarpiece had just arrived to Florence and was set up in the chapel of the hospital of Santa Maria Nuova, where many Florentine painters went to see this work, done by a foreign artist. Soon thereafter, Ghirlandaio was commissioned to paint the altarpiece and wall frescoes in the Sassetti Chapel in the Church of Santa Trinità, and his altarpiece shows a Netherlandish influence in the style of realism and the symbolic reading. Ghirlandaio was known for his ability to measure **linear perspective** with a high degree of accuracy, and his fresco technique was superior to most artists in Florence. Leonardo certainly would have seen Ghirlandaio's *Last Supper* fresco in the convent of the Ognissanti Church in Florence, done in 1480, which was one of three Last Supper scenes painted by Ghirlandaio, and most scholars assume Leonardo sought to alter Ghirlandaio's composition in his ***Last Supper***, done in **Milan** a few years later by moving Judas to the same side as Christ and the apostles, and creating an undulating line of heads to break the horizontal format of the narrative. *See also ANNUNCIATION*; BOTTICELLI, SANDRO; CASTAGNO, ANDREA DEL; CLASSICISM; POLLAIUOLO, ANTONIO DEL; UCCELLO, PAOLO.

GIAMPIETRINO (worked 1495–1549). Lombard painter Giampietrino, or Giovanni Pietro Rizzoli, was a member of Leonardo's studio who continued to work in Leonardo's style after his death. His productive career is credited with spreading Leonardo's style through his copies of Leonardo's work and his original panels done in Leonardo's style, for example, a ***Mary Magdalene***, housed in a Swiss private collection, which is sometimes attributed to Leonardo. Giampietrino is credited with painting the best copy of Leonardo's ***Virgin of the Rocks***, called the *Cheramy Virgin of the Rocks* (Switzerland, Cheramy Collection), and an **oil**-on-canvas copy of Leonardo's ***Last Supper***, dated to about 1520 (London, Royal Academy of Arts), an excellent full-scale version that was consulted during the most recent restoration of Leonardo's painting, done in 1978–1998.

Leonardo's *Virgin of the Rocks*, known in two versions, one at the Louvre Museum in Paris and one in the National Gallery in London, was copied by many artists, some of whom were students of Leonardo. Of the more than 50 known copies, two of the better versions include **Bernardino de' Conti's** painting, located in the Church of San Sebastiano a Biella, and **Giovanni Antonio Boltraffio's** copy, in the Treccani Collection in **Milan**. The Cheramy copy, located in the Cheramy Collection in Switzerland, is an excellent copy that has also been attributed to Leonardo by art historian **Carlo Pedretti** based on mid-1800s identifications and is called the third version. This is an oil-on-wood painting that has been transferred to canvas, measuring 81 x 48 inches. Identical to Leonardo's work, the painting reveals only subtle differences in facial type and shading

of the Virgin's face. *See also* LEONARDESCHI; PAINTINGS.

GIANT CROSSBOW. *See* CROSSBOW; INVENTIONS.

GINEVRA DE' BENCI. This painting, an **oil** and **tempera** on poplar panel, measuring 15.3 x 14.4 inches and located in the National Gallery of Art in Washington D.C., was first attributed to Leonardo in 1866, and is generally recognized as Leonardo's first extant portrait, dated c. 1474. Here we see a bust-length figure of a young woman with her face angled slightly to disp ay depth, looking out at the viewer with heavily lidded brown eyes and a placid porcelain complexion. The painting originally showed more of her arms, perhaps down to her lap, but the bottom portion was cut off at one point, presumably due to damaged wood. The sitter is uniformly identified as Ginevra, the daughter of Amerigo de' Benci, done in 1474, on the occasion of her marriage at the age of 17, to Luigi di Bernardo Niccolini. The back of the painting shows a branch of juniper with the **Latin** phrase "beauty adorns virtue," which linked Ginevra to the **Medici** circle of humanists and diplomats in **Florence**, several of whom wrote sonnets lauding her beauty, one of whom was Lorenzo de' Medici, who wrote two sonnets about her.

Indeed, the young woman looks out in *riposo*, or restraint, as her dark blond curls frame her oval face. **Light** reflects off each individual strand of hair, a technique Leonardo was able to achieve with the use of a paintbrush made of one strand of horsehair dipped in oil pigment, providing a richer coloring and more minute detail than possible with tempera paint. Ginevra wears a brown dress laced at the bodice with a blue ribbon and trimmed in delicate gold embroidery over a barely visible white silk undershirt pinned with a gold button. Her hair is held in a bun with a black veil that hangs down over her shoulders. This level of intricate realistic detail was unprecedented in Florentine **Renaissance** painting, and it certainly must have dazzled viewers more than any fine jewelry or rich setting. Instead, Ginevra's head is framed by a juniper tree of spikey brown branches, suggesting it is autumn. A landscape opens up over her left shoulder to reveal a softly painted still pond surrounded by slender trees of brown leaves. Farther back, the color shifts to a rich blue, demonstrating Leonardo's use of **atmospheric perspective**, first introduced by Florentine artists in the early 1400s. While Leonardo's later **portraits** were increasingly characterized by a soft **sfumato** and hazy, golden lighting, this painting introduces his characteristically idealized realism. *See also BELLA PRINCIPESSA*; *BELLE FERRONNIÈRE*, COLOR; *LADY WITH AN ERMINE*, LANDSCAPES, *MONA LISA*; *PORTRAIT OF ISABELLA D'ESTE*; PAINTINGS.

GIOVIO, PAOLO (1483–1552). Italian scholar and physician Paolo Giovio is best known for his biographical history of famous men called *Vitae virorum illustrium*, written in 1549–1557. His eyewitness accounts of the Italian Wars; his faculty position in natural philosophy at the University of **Rome**; an appointment given to him by Pope **Leo X**, whose memoir Giovio wrote, and his position as physician for Cardinal Giulio de' **Medici**, who later became Pope Clement VII, lent interesting details to his descriptions of famous men. Giovio included a brief account of Leonardo's life in his unfinished *De vins illustribus* of 1527, where he described Leonardo's anatomical studies and confirmed that Leonardo had carefully written down his observations so they could be published for the benefit of future artists. He also noted that Leonardo was a genius of invention and a judge of beauty and elegance. Giovio is one of four contemporary biographical sources for Leonardo that include a brief account by Antonio Billi expanded upon in the **Anonimo Gaddiano** and the most detailed biography by **Giorgio Vasari**. Otherwise, Leonardo's life has been pieced together from brief documentary notations made of his commissions and other activities throughout his life that have been reconstructed by later art historians to provide a fuller overview of the artist's life and career. *See also* ANATOMY; CLASSICISM, HUMANISM, *LUCAN PORTRAIT OF LEONARDO*; TORRE, MARCANTONIO DELLA, *TREATISE ON PAINTING*.

GOES, HUGO VAN DER (c. 1430/1440–1482). Painter Hugo van der Goes was an important Flemish artist of the mid 1400s known specifically in **Florence** because of his *Portinari Altarpiece*. He was born in or near Ghent, a major artistic center in the Early **Renaissance**, and rose to importance when his rival, Joos van Wassenhove, or Justus van Ghent (c. 1410–c. 1480), moved to Italy in 1470, to work for Duke Federico da Montefeltro of Urbino. By then, Flemish art had become increasingly popular in Italy, as patrons appreciated the incredible level of realistic detail that characterized Flemish art, in addition to the Flemish mastery of **oil** paint. In Florence, however, the art commissions were dominated by local artists, and when the *Portinari Altarpiece* was set up in the hospital of Santa Maria Nuova in Florence, it was not without controversy. Nonetheless, these local artists flocked to visit this foreign painting and see firsthand the famous style of these Northern European artists.

The large altarpiece was commissioned by Tommaso Portinari, a Florentine banker who worked for a branch of the **Medici** bank in Bruges. He wanted to commission a significant work of art to decorate this wealthy hospital to remind visitors of his family's relation to the founder of the hospital in the late 1200s, who, incidentally, was the father of Dante's Beatrice. Furthermore, since Portinari had lived in Bruges for more than 40 years, the painting would serve to remind the viewer of his international importance and ties to Florence.

The painting is a large triptych with the *Adoration of the Shepherds* in the center, flanked by side panels of the Portinari family together with their patron saints. When the painting was completed in Bruges, it was shipped to Pisa and then sent on a barge down the Arno to Florence, where it arrived in May 1483. The influence of this composition was immediate and can be seen in **Domenico Ghirlandaio's** *Adoration of the Shepherds* in the Sassetti Chapel in Santa Trinità in Florence, from c. 1485. Although Leonardo was living in **Milan** at this time, he would have seen this work during one of his frequent trips back to Florence, and certainly van der Goes's use of oil paint would have interested Leonardo, in addition to his microcosmic view of nature, similar to Leonardo's studies of nature. Specifically, in the foreground of the central panel, an apothecary jar and glass vase are both filled with flowers, demonstrating an incredible botanical accuracy, while angels cast shadows and the architectural materials show details of chipped marble and stone with mortar. *See also* BOTANICAL STUDIES, PAINTINGS.

GRAN CAVALLO. *See* SCULPTURE.

GROTESQUES. *See* CARICATURES.

GUILD OF SAINT LUKE. *See* CONFRATERNITY OF SAINT LUKE.

H

HEAD OF A WOMAN (LA SCAPIGLIATA). The *Head of a Woman* is an unfinished **monochromatic** brush drawing of a woman's head, tilted downward. The work is done on poplar wood and is located in the National Gallery of Parma, dated c. 1508 and attributed to Leonardo. Here we see a panel measuring 9.7 x 8.3 inches, showing the outline of a woman's face, carefully detailed in lead-white paint, while her waving hair is sketched out around her and her shoulders are loosely drawn in and incomplete. The head takes up the entire space of the work, and the background is primed but not painted. A document associated with the painting states that it was located in the Gonzaga Palace in **Mantua** in 1531, and it was mentioned there again in 1627, which would suggest it might be a painting of the Virgin Mary that Duchess Margaret Paleologa, the wife of Federico II Gonzaga, requested from Leonardo in 1501. It is not clear if Leonardo ever began this work, however, and scholars have instead identified the work as possibly Leda, from ***Leda and the Swan***, a lost work of Leonardo's known through student copies. Nevertheless, it does reveal the style of Leonardo's late work, although the circumstances of its completion are mysterious. *See also* SESTO, CESARE DA; LEONARDESCHI; PAINTINGS; PORTRAITS.

HELICOPTER. Leonardo's helicopter prototype, also called an aerial screw, is perhaps his most famous invention, although it is not clear whether he ever made a working model. A sketch of this **flying machine** is found in a drawing in the ***Paris Manuscripts*** B, fol. 83v, and dates from c. 1489. Next to the drawing, he explained, "If this instrument made with a screw be well made, that is to say, made of linen of which the pores are stopped up with starch and be turned swiftly, the said screw will make its spiral in the air and it will rise high." Leonardo's studies of birds in flight allowed him to understand that air compression could help elevate the machine by leaning inward beneath the linen, which was designed in a spiral shape attached to a central pole. The screw mechanism would move counterclockwise after a wound-up spring released to spin the screw and push the air downward.

Leonardo used the screw to power many different **inventions**, so this machine is actually a variant on the many other locomotion machines he envisioned. This movement could also have been seen in nature, by witnessing leaves or seed pods spinning to the ground, a natural movement that was replicated in wooden tops that were either spun on the ground or into the air, where they would stay aloft for a short time period. Leonardo's helicopter was finally built by a Canadian design team called AeroVelo from the University of Toronto, who submitted their winning design to the Igor I. Sikorsky Human Powered Helicopter Competition. *See also* AERODYNAMICS; *CODEX ON THE FLIGHT OF BIRDS*; DRAWINGS; ENGINEERING; NOTEBOOKS.

HOLY INFANTS EMBRACING. Documents describe a small painting by Leonardo of the infant Christ embracing his infant cousin John

the Baptist set against a hazy background. The painting is not extant but is known today in about 30 copies. The infants are a variation on those found in the ***Virgin of the Rocks***, and the original painting was likely done in **Milan** during the same time period. This small **oil**-on-panel copy is located in the Capodimonte Gallery in Naples and shows a cropped view of the infants, softly painted in a deep **chiaroscuro**. A version by Leonardo's assistant, **Marco d'Oggiono**, in Windsor, in the Royal Library, shows the infants seated on the ground against a more fully detailed rocky outcrop that opens on the right to a distant landscape view with mountains in the background. **Bernardino Luini** copied the infants into a scene of the *Holy Family with Saint John* (Madrid, Prado Museum). Leonardo's oeuvre continues to be questioned, as numerous works remain disputed in their attribution and identity. Some of Leonardo's lost works are described in archival documents and early biographies, and some of those works can be visualized through later copies. *Holy Infants Embracing* is a good example of this reconstruction. *See also* LANDSCAPES, LEONARDESCHI, PAINTINGS.

HOMOSEXUALITY. Many people have been interested in Leonardo's sexuality throughout the years, despite the fact it appears to have had no impact on his career. Despite his enormous amount of writing, little reveals his personal interests. Nonetheless, documents show that when Leonardo was 24 years old, he and several other young men were arrested in **Florence** for sodomy after they were denounced anonymously for their affairs with the well-known Jacopo d'Andrea Saltarelli, a 17-year-old artists' model and male prostitute who had been convicted of sodomy earlier that year. The accusation, left in the letter box at the government palace on 9 April 1476, also included a tailor named Baccino, goldsmith Bartolomeo di Pasquino, and Leonardo Tornabuoni. Charges were dismissed for all five participants, likely through the intervention of the noble Tornabuoni family.

Contemporary biographers, one of whom was **Giorgio Vasari**, never mentioned Leonardo's homosexuality, while scholars since then have vacillated between considering him celibate and sexually active, while noting some of his sexualized paintings done later in his life, notably his ***Saint John the Baptist***, which was the model for the charcoal drawing *Incarnate Angel* (c. 1515, Paris, Louvre Museum) from Leonardo's workshop, thought to be a portrait of his student **Salai** with an erect phallus. Despite the fact that homosexuality was illegal, it was rarely prosecuted in Florence, where it has been widely documented as being fairly common during this era. *See also* ANATOMY; FREUD, SIGMUND, RENAISSANCE.

HUMANISM. At the center of the **Renaissance** was a literary, philosophical, and artistic revival shaped by the idea of humanism that emerged from antiquity. This concept was first described in 1345, by Italian poet Francesco Petrarca (1304–1374), while examining the ancient manuscript holdings of the Chapter Library attached to the Cathedral of Verona, and it ushered in a revived interest in the study of grammar, logic, rhetoric, arithmetic, **geometry**, **music**, and **astronomy**—disciplines once considered important to fulfilling one's civic duties. In Verona, Petrarca discovered a collection of letters written by Roman scholar and politician Marcus Tullius Cicero (106–43 BC), a lawyer who introduced Greek philosophical concepts, notably the idea of *humanitas*, into Roman culture and gave primacy to the use of refined rhetorical skills that would allow people to live in harmony and in accordance with the law. Cicero's concept of *humanitas* was related to ancient Greek discussions on the unique character and achievements of humans, combined with a set of traits outlined in Roman antiquity on how humans could better themselves through education and a moral code of conduct to become a "gentle-man," as opposed to a man who succumbed to lower, animalistic instincts and irrational thought. This involvement with learning allowed for polite interactions in society and the cultivation of benevolence and kindness toward others, and it encouraged political engagement.

Therefore, in antiquity, the term was used to define a kind of scholarship that celebrates human endeavors and encourages human

progress. It has also been used to refer to humankind's capacity for rational thought, as opposed to the instinctual behavior of animals, and this way of thinking ultimately led to empiricism and rationalism against fatalism and superstition. This quest for knowledge influenced artists, who sought to elevate artistic discourse beyond the technical focus of the medieval artisan trades to include a fuller intellectual basis that anticipated modern notions of the artist as a cultural emissary. Humanism and its ideas were discussed among wealthy merchants, in the aristocratic courts of Europe, the papal court in Italy, and the Holy Roman Empire in Germany, and helped to expand the academic disciplines studied by students of every level in the Renaissance. *See also* CLASSICISM, FICINO, MARSILIO; FLORENCE, MIRANDOLA, GIOVANNI PICO DELLA.

HYDRAULICS. Leonardo's interest in hydraulics was shaped by his study of water, the understanding of which Leonardo surmised was fundamental to a broader understanding of how the universe functions. His understanding of the dynamic force of water also derived from various commissions he received for hydraulic **inventions**, some of which were for warfare, while other hydraulic inventions were devised in the creation of the **ideal city**. While most of his hydraulic work was done in the service of Duke **Lodovico Sforza** in **Milan**, Leonardo also created a project in **Florence** to divert the Arno River around Pisa (*Study for the Arno Canal*, c. 1503, pen and ink on black chalk, Windsor, Royal Library, 12279), he designed dykes to protect the Republic of **Venice** from invasion by sea, and he devised harbor and canal projects in **Rome** and for **Cesare Borgia**. Thus, Leonardo's hydraulic studies, found throughout his **notebooks**, constituted a lifelong interest.

His hydraulic inventions primarily included water pumps and wells, canals, and drilling machines needed to collect, store, and move large amounts of water. Leonardo's interest in hydraulics perhaps began during his apprenticeship with **Andrea del Verrocchio**, who was known as an experienced hydraulic engineer. Although Leonardo did not invent any new water pumps, he made improvements to existing machinery, for example, an improved Archimedean screw that reduced leakage, and he used the Archimedean screw in a new waterwheel design that could bring more water up into a water tower, and his water pumps were also used to drain swamps. One of his more beautiful notebook pages depicts various screws and systems for raising water, which appear on fol. 26v of the ***Codex Atlanticus***. Here, Leonardo shows five different machines used for lifting water, with several details of the screws and pulley systems Between the drawings, Leonardo writes out short paragraph descriptions of what he is trying to achieve.

Leonardo also sketched different types of drilling machines, both vertical and horizontal, using the same screw system, and for his canal systems he invented a new miter lock that allowed for a smoother transfer of boats through a canal. His large-scale water diversion projects never materialized due to cost and logistics, but his plans to link the city of Milan to the sea were instrumental in Leonardo's theoretical conception of the ideal city. *See also* BRIDGES; CANAL LOCK; *CODEX ARUNDEL*; *CODEX LEICESTER*; ENGINEERING; HYDRODYNAMICS; HYDROSTATICS; ROMORANTIN; WATER STUDIES.

HYDRODYNAMICS. Hydrodynamics is a scientific branch of physics focused on the study of the movement of fluids and their interaction with objects, as opposed to **hydrostatics**, which is focused on the study of fluids at rest and their pressure and surface tension. Leonardo displayed an interest in both areas with his **water studies**. One example of his hydrodynamic studies is an ink and red chalk drawing of water flowing past an obstacle the size and shape of a book that is placed first perpendicular and then parallel to the flow of water. The first presentation shows more turbulence in the water, as the water flows around a wider surface to curl back around into the flow pattern. The drawings, dated to c. 1510–1513, take up about one-fourth of the folio, which is then covered with three columns of annotations (United Kingdom, Royal Collection Trust, RCIN 912660). Leonardo observed

that flowing water follows various patterns and is therefore subject to natural laws rather than random or chaotic movement. In his annotations, he sought to define five different principles of water movement and interaction with air. *See also* ENGINEERING; HYDRAULICS; INVENTIONS, NOTEBOOKS.

HYDROSTATICS. While **hydrodynamics** is focused on the movement of water, hydrostatics is focused on the principles of water at rest. Leonardo was interested in both fields of study and used his **water studies** for his various hydraulic **inventions**. His hydrostatic studies focus on why some objects float on water while others sink, why oil does not mix with water, and why the surface of water is flat. Some of these things were observed and studied in antiquity by anyone building a boat or fountain, while the scientific principles of hydrostatics were first described by Archimedes (c. 287–c. 212 BCE), the ancient Greek engineer, mathematician, and inventor from Syracuse. His *On Floating Bodies*, a two-volume treatise written in Greek in about 250 BCE, is the first-known study of hydrostatics and was known in Italy through a medieval **Latin** translation. In this work, Archimedes cataloged his observations into general principles, including such things as fluid displacement and how denser solids sink but are lighter than the same solid above water. He observed the law of fluid equilibrium and the theory of buoyancy, which he described as the upward force of an object submerged in water that is equal to the weight of the displaced water, called Archimedes' Principle.

Leonardo developed these ideas further with his observations of surface tension, which is the tendency of a fluid to appear sticky or elastic where the liquid molecules meet the air molecules and can be seen when a drop of water seems to hang in place and change shape before falling. Indeed, Leonardo is credited with recording the first scientific observation of capillary action, or wicking, by observing that when a tube is dipped in water, the water rises up in the tube. He likely also observed how a paintbrush does not only absorb paint into the brush hairs, but also draws paint up between the hairs, so the hairs hold the paint at a certain volume into place before dripping. The principles of capillary action can also explain how plants draw water upward and how fluids are absorbed into fabrics. In Leonardo's ***Madrid Codices***, volume 1, fol. 152r, he shows three different nozzles to determine from which one water will flow at the greatest force. The force, or "violence," he mentions is calculated from a scale suspended below the falling water. Here he observes the hydrostatic paradox that the violence of the water is determined by the distance from the nozzle to the water surface, but not from the volume of water falling from the container above. *See also* ENGINEERING; HYDRAULICS.

I

ICHNOLOGY. Ichnology is a specific branch of **geology** focused on the study of natural features generated by living creatures, for example, human or animal footprints, insect mounds, or burrows. Humans and animals interact with their environment, and the clues they leave behind can be analyzed to explain behavior patterns throughout time. Ichnology is often considered a branch of paleontology, which is focused specifically on the era prior to the advent of human existence worldwide and includes the study of fossils, which can tell us about evolution, but ichnology is actually divided into two areas, one that focuses on ancient material and one that looks at more modern, extant living creatures. While this branch of science is a modern area of specialization, **Renaissance** artists and scientists like Leonardo who were interested in a careful examination of nature made some of the first ichnological observations.

Paleontology and the study of body fossils is known to have been introduced in the Renaissance, and the term *geology* was first used by Bolognese naturalist Ulisse Aldrovandi (1522–1605), who correctly identified some trace fossils and understood bioerosional traces. Prior to Aldrovandi's work, Leonardo considered these traces to have organic origins, while Aldrovandi incorrectly suggested that some could come from water circulating within rocks. Some of Leonardo's notebook sketches show his awareness of the difference between these two subfields of geology. In the ***Codex Leicester***, he describes his observations on **astronomy**, explains the movement of water, and describes fossils and other geological formations. On fol. 8v, he observes marine shells found in the Apennine Mountains, which were originally living animals petrified into rock, mixed with ocean sediment, and rather than suggesting this was proof of the flood found in the Book of Genesis (chapters 6–9), he argued that shifts in land and sea throughout the centuries resulted in animal residue spread out across different environments. In his argument, he calculates that these slow-moving animals could not have traveled such far distances in 40 days, nor could waves carry these shells, which would have been too heavy to be propelled such a long distance into the mountains. *See also* LANDSCAPES; NOTEBOOKS; WATER STUDIES.

IDEAL CITY. Leonardo began his ideal city plans from 1487–1489, while working for **Lodovico Sforza** in **Milan.** His basic concept appears in ***Paris Manuscript*** B, fols. 16r and 37v, where he began to explore ideas for reducing congestion, dust, mud, and dirt, while separating out the functional aspects of the city from the more leisurely activities. Leonardo's city would be spacious, with geometrically arranged roads and buildings, all in close proximity to canals for transportation, water drainage, and storage. These city plans combined Leonardo's interests in water, **engineering**, fortifications, and architectural designs.

After the plague devastated so many late medieval towns throughout Europe, doctors and scientists began to study the impact of healthy living patterns on the spread of

disease, and they rightly realized that clean water, fresh air, and an organized city plan could help stave off future plagues. Leonardo's ideal city integrated a commercial canal system and a sewage system separated from the system used to provide drinking water. He also provided two levels to his city, with a lower level for tradesmen and workers, and an upper level for leisurely activities. He planned wide streets, with **bridges** at two levels to separate wheeled traffic from pedestrian traffic. Horses would live in spacious stables, and housing would have fresh-air vents. Finally, the visible parts of the city included beautiful buildings in the classical style, while the functional structures would be hidden from view.

Ideal cities have been theorized throughout history based on current desirable aesthetic, rational, and moralizing reasons. Most ideal city plans of the **Renaissance** are based on a grid, which harks back to ancient Roman town planning. The idea of an ideal city originated in antiquity, and in Plato's *Republic* he introduced a philosophical rationale for this concept. Leonardo was most influenced by **Antonio di Pietro Averlino Filarete's** *Sforzinda*, designed for Lodovico Sforza in the 1460s, as an eight-pointed, star-shaped fortified city surrounded by a moat. While Filarete focused on fortifications, other ideal cities were centered around the reintroduction of the classical style of **architecture**.

A horizontally oriented rectangular **tempera** painting called the *Ideal City* from about 1470, whose artist is unknown (Urbino, Galleria Nazionale delle Marche), shows a city view with a classical, round church in the middle, flanked by paved, straight streets lined with elegant, three-story palaces of consistent size and layout, with slight variations in style to add interest to their designs. The foreground palaces have open loggias at street level and open porticoes at the upper level with Corinthian columns and exteriors clad in marble veneer. Two fountains balance one another in the foreground, one on either side of the temple. The stone paving reveals the grid upon which the city was carefully measured, providing mathematical symmetry and proportions. Interestingly, no people appear in this city plan; indeed, none of these ideas ever came to fruition in their entirety, while some aspects of these plans, including the more open spaces, straight streets, and emphasis on sanitation have influenced modern city plans. *See* CLASSICISM; GEOMETRY; HYDRODYNAMICS; MARTINI, FRANCESCO DI GIORGIO; MATHEMATICS; MILAN; ROMORANTIN; VITRUVIUS, MARCUS POLLIO; WATER STUDIES.

IMOLA TOWN MAP. *See* CARTOGRAPHY.

INGRES, JEAN-AUGUSTE-DOMINIQUE. *See* PAINTINGS OF LEONARDO.

INVENTIONS. The history of Leonardo's inventions is tied to studies of his **notebooks**, where he made thousands of annotated sketches of things found in nature. His studies were both artistic and scientific, and they spurred him to create such theoretical models as various **flying machines** based on his study of birds, practical solutions for his artistic needs like a controlled-flame furnace, such practical technological military advances as his triple-barrel cannon and giant **crossbow**, and improvements to existing inventions like the **clock**. Most of Leonardo's inventions were theoretical and only fully realized hundreds of years later.

Many of Leonardo's studies focused on aeronautical inventions. Aeronautics, the ancient Greek term for navigating through the air, has long fascinated humans, who have theorized many different types of flying machines, first by trying to mimic bird flight by fashioning wings and jumping off cliffs. Ancient and medieval Islamic and Chinese scholars then sought to understand how flight worked and during the **Renaissance** Leonardo was one of the earliest scientist-artists to anticipate modern technological advances in aeronautics. For example, he examined medieval studies of wing flapping, which anticipated the ornithopter, a machine that flies with the flapping of mechanical wings. He also designed a prototype for a **helicopter**, conceived as an aerial screw with rotating wings that reveal a basic understanding of air resistance, as well as the knowledge that a human-controlled

flying machine would need an additional power source. He created a **parachute** modeled on existing kite technology, a mechanical dragonfly and eagle, and numerous prototypes of mechanical wings.

Furthermore, to study flight scientifically, Leonardo needed to measure the speed of wind, and for this, he invented the **anemometer**, named after the Greek word for wind. Today the anemometer is usually designed similar to a weather vane, with several small cups attached to horizontal limbs of a vertical rod that capture the wind and turn the limbs. The number of revolutions in a set amount of time can be used to calculate the wind speed. The first known anemometer was designed in about 1450, by **Leon Battista Alberti**, and consisted of a disk set perpendicular to the wind that would tilt to measure the force and spin to calculate its velocity. Alberti's ideas, formulated in the context of his architectural commissions, laid the foundation for many of Leonardo's inventions. During the 1480s, Leonardo made various sketches based on Alberti's anemometer design as part of his studies of birds in flight and human flying instruments, and one plan can be found in the ***Codex Atlanticus***, fol. 675. Here, Leonardo's drawing shows a rectangular paddle hanging loosely on a hinge that tilts upward when hit by wind. The angle of the tilt is measured by a protractor-like arched piece of wood perpendicular to the paddle that shows the force of the wind. In Leonardo's drawing, he writes that the instrument could measure distance, with the addition of a clock to measure time.

Many later models of Leonardo's design still exist. English scientist Robert Hooke (1635–1703) designed a similar anemometer and is sometimes mistakenly credited with its invention, while further refinements include the cup anemometer, which anticipated the version most commonly used today, invented in 1846, by Irish astronomer Thomas Romney Robinson (1792–1882), the son of painter Thomas Robinson. Leonardo may never have made a working model of his instrument, but numerous wooden reconstructions of his scientific ideas are displayed in various exhibitions throughout Europe and the United States.

Leonardo's practical inventions needed to advance his artistic innovations include numerous chemical experiments that helped Leonardo create new oil pigment recipes, as well as their application on plaster and wood panels. His studies of a furnace are particularly interesting, in part because of their comparison with his studies of how the human heart generates heat. He conceived of a twin-chambered furnace with a central tower used to store wood, which would be continuously fed into the fire through gravity, cutting back on the number of times the furnace needed to be loaded. He also sought new methods of temperature control and consistency by experimenting with furnace chambers placed at various distances from the fire, together with different placements for the air-intake openings and a continuous cooling distiller with a large surface area kept at a consistent cooling temperature through external cold-water tanks (*Codex Atlanticus*, fol. 989v). When Leonardo sought to create a colossal equestrian monument to Francesco I Sforza in Milan, he hoped to cast the giant bronze **sculpture** in one piece, which required an enormous furnace, as well as a machine needed to transport the giant mold to the foundry.

Leonardo was also commissioned to provide solutions for military strategies and political advances, which included controlling water sources and creating new military equipment for **Piero Soderini** in **Florence**, Duke **Lodovico Sforza** in **Milan**, and their rival, **Cesare Borgia**. Leonardo designed a revolving **bridge**, an ingenious solution for crossing bodies of water quickly, for Lodovico Sforza, featuring a wheeled wooden bridge that could be folded together and transported to a river or moat, where it could then be swung open with a counterweighted rope and pulley system that maximized mobility for foot soldiers. Leonardo also designed a **33-barrel organ** that could fire cannon rounds simultaneously by rotating in rows so that one row could be reloaded while another row was fired. The cannon barrels resembled the pipes of a musical organ, and this instrument anticipated the modern machine gun. Other military inventions included the triple-barrel cannon; the armored car,

which anticipated the modern **tank**; and the giant crossbow, found in the *Codex Atlanticus* (fol. 149a). Although never built, Leonardo's crossbow was a weapon that would have had a greater range for hurling large stones; it could be moved on six sets of wheels, and with its width of 81 feet, it was primarily meant to intimidate the enemy.

Leonardo's inventions also included a mixture of practical and theoretical explorations, for example, an efficient spring-driven clock, a **self-propelled cart**, scuba gear, a **submarine**, and a **time machine**. His self-propelled cart is considered the first robot, which Leonardo expanded on to theorize a robotic knight known in fragmented form throughout his notebook sketches. Leonardo's robotics were primarily used for festivities in Milan, where such innovations would have marveled the audience. The wheeled robotic knight would have been made with a system of pulleys and gears on a cable system that allowed for independent movement, the cornerstone of robotic technology. Like many of Leonardo's inventions, the robot has fascinated modern scientists. Roboticist Mark Rosheim built Leonardo's robotic knight in 2002, and showed how it could walk and wave. Furthermore, Leonardo's robot principles centered around an efficiency of parts and simplicity of construction that inspired some of the robot designs created for NASA. *See also* AERODYNAMICS; ANATOMY; AUTOMATON; CHEMISTRY; *CODEX ON THE FLIGHT OF BIRDS*; ENGINEERING; MUSIC; *PARIS MANUSCRIPTS*.

ISLEWORTH MONA LISA. In 1913, English collector Hugh Blaker discovered this **oil**-on-canvas painting in a Somerset country home in England. He bought the painting and took it to his art studio in Isleworth, where he confirmed its attribution to Leonardo and argued that it was the first version of the ***Mona Lisa*** and the one sketched by **Raphael** in a drawing now located in the Louvre Museum in Paris. Based on **Giorgio Vasari's** notation that the *Mona Lisa* remained unfinished, some scholars have suggested that the Isleworth version was left unfinished in **Florence** and completed by another artist, while Leonardo painted the more famous Louvre version later on for his personal collection. The painting was then bought by Henry Pulitzer, who published a book presenting evidence to bolster the attribution to Leonardo. Upon Pulitzer's death, the painting was locked in a Swiss vault, and in 2012, an organization called the Mona Lisa Foundation was formed to study the painting's attribution. Yet, scholars remained divided on the history of this painting. In 2014, PBS aired a documentary entitled *The Mona Lisa Mystery*, which examined this work in detail. Several other versions of the *Mona Lisa* exist, notably an excellent copy in the Prado in Madrid done by Leonardo's workshop, and most of these copies have been scientifically confirmed to be close in date to the Louvre *Mona Lisa*. *See also BELLA PRINCIPESSA*; *BELLE FERRONNIÈRE*; GINEVRA DE' BENCI; LEONARDESCHI; MUSEUMS; *PORTRAIT OF ISABELLA D'ESTE*; PORTRAITS.

K

KEMP, MARTIN (b. 1942). Martin Kemp, emeritus research professor of art history at the University of Oxford, is one of the leading experts on Leonardo. Kemp has published extensively on Leonardo and worked to bring together the artist's scientific interests with his art and dispel the many myths about Leonardo that appear frequently in popular literature. Most recently, Kemp's extensive archival work has provided further clues to the identity of Leonardo's mother, Caterina, who Kemp argues was Caterina di Meo Lippi, a poor 15-year-old orphan who lived with her grandmother in an old farmhouse outside of **Vinci**. Kemp, together with Giuseppe Pallanti, in their recent publication, *Mona Lisa: The People and the Painting*, also provide a fuller examination of the career of ***Mona Lisa's*** husband, a silk and sugar merchant who also purchased slaves.

Kemp's educational background in both the natural sciences and art history as a student at Cambridge University and the Courtauld Institute of Art provided him the basis for his close analysis of Leonardo's understanding of **optics** and naturalistic representation in art through studies of **anatomy** and botany, among other scientific disciplines. Kemp has served as an advisor to scientists interested in recreating Leonardo's experiments, notably his **flying machines**. In 2010, he, together with French engineer Pascal Cotte and a team of scientists, adapted the technical methods of forensic science to authenticate a portrait, now called ***Bella Principessa***, where they identified Leonardo's fingerprint. Kemp's monograph *Leonardo da Vinci: The Marvellous Works of Nature and Man* remains the standard monograph on Leonardo. *See also* CLARK, KENNETH MACKENZIE; *LADY WITH AN ERMINE*; PEDRETTI, CARLO; PORTRAITS; *TOBIAS AND THE ANGEL*.

L

LADY WITH AN ERMINE. This small painting, a portrait of Cecilia Gallerani (1473–1536), is one of Leonardo's four female **portraits.** Now located in the National Museum in Krakow, Poland, it was painted by Leonardo in about 1489–1490, while in **Milan.** It is an **oil**-on-walnut wood panel that measures 21 x 15 inches and depicts a half-length image of a young woman with her torso turned to the viewer's left, while her head turns behind her shoulder to gaze at something attracting her attention outside the painting. This dynamic three-quarter view was a format introduced by Leonardo, and it reveals his interest in depicting figures in motion.

The young woman wears a blue and red dress trimmed in gold thread, with sleeves tied together with blue ribbons. In her arms is a white ermine, who the lady pets, as the alert animal follows the woman's gaze. Her left hand, stroking the back of the animal, is carefully painted to show anatomical realism but enlarged to give the impression that it projects out into the viewer's space. Her beaded necklace wraps twice around her neck and plunges down the front of her dress, which draws the viewer's eye from the ermine to the woman's exposed collarbones. Her face is softly modeled with shading, giving her a three-dimensional form. She wears her hair in the Milanese courtly fashion, carefully combed, parted in the middle tied under her chin, and clasped in a braid behind her head, while a thin blue ribbon and gold chain forms a headpiece across her forehead similar to the headpiece worn by the woman in ***Belle Ferronnière.*** This hairstyle was unique to Lombardy and not seen in **Florence** during this time. The background is a uniform dark black that was repainted in the mid-1800s over Leonardo's original blue-gray background. Leonardo's fingerprints have been discovered in the paint based on the technical work overseen by **Martin Kemp**, which suggests Leonardo sometimes used his fingers instead of a paintbrush to blend his pigments.

This beautiful woman was the mistress of Duke **Lodovico Sforza** of Milan. She was born in Siena, but her father worked in the ducal court in Milan, and although the family was not noble, they were highly educated, and Cecilia studied the humanities and poetry. She was promised in marriage at the age of 10, to a member of the Visconti family, but later she sued to have the marriage annulled, at which point she moved into an apartment in the Sforza Castle. When Lodovico's wife, Beatrice d'Este, found out about her rival, Cecilia was moved out of the castle and arranged in marriage to Lodovico Carminati, Count of Bergamino. She had four children with her husband and one child with Duke Lodovico. This portrait shows Cecilia at the age of 16, soon after she became the duke's mistress. The ermine, a unique household pet, provided the pure white fur used in many royal overcoats. Leonardo described the animal in his **notebooks** as modest and clean, and he likely used the animal here to symbolize Cecilia's purity. The ermine was also a personal

emblem of Duke Lodovico, which provides further identification of the sitter as his mistress. The animal has also been described as a white ferret or weasel which could symbolize her pregnancy.

Cecilia was an important figure in the ducal court in Milan, where she held meetings to discuss art and philosophy. These meetings anticipated the literary salon meetings of the next centuries, where a host, often a wealthy female patron, would gather together a small group of intellectuals to discuss a topic of her choosing via polite, shared discourse that anticipated modern conversation protocol. Her salon meetings were the model used by wealthy northern Italian women, including Giovanna Dandolo, Isabella d'Este of **Mantua**, and Elisabetta Gonzaga. Perhaps she is not so much gazing out of the painting, then, but listening to a speaker, a piece of **music**, or a poem recited at one of her intellectual gatherings. *See also BELLA PRINCIPESSA; GINEVRA DE' BENCI; MONA LISA; PORTRAIT OF ISABELLA D'ESTE.*

Leonardo da Vinci, *Lady with an Ermine*, c. 1489–90, oil on walnut wood, 21 x 15 inches, Kraków, National Museum.

LANDSCAPES. Renaissance art is characterized by an increase in the realistic depiction of the natural world, and landscape views moved from a secondary role in art to a central role, where landscapes were not only imbued with symbolic meaning, but also reflected the new scientific advances of the era. Leonardo was very interested in landscapes, which appear in both his **paintings** and **drawings**. He drew carefully from nature, but rather than topographically accurate views, his landscapes are imagined from the varied mountains and valleys of Central and Northern Italy. Most of Leonardo's paintings feature distant mountain views with jagged peaks and a bluish-gray atmospheric palette. Indeed, the Alps stretch east and west across Northern Italy to form natural territorial boundaries, while the Apennines run north and south through the center of Italy like a spine, both of which were near where Leonardo lived and worked. The rolling mountains around **Florence** and the taller, more jagged mountains north of **Milan** were therefore major inspirations for Leonardo in his nature studies.

Leonardo's first impressions of the mountains that appear in many of his paintings can be found around his birthplace of Anchiano, specifically Monte Albano, which certainly must have loomed large in the young Leonardo's childhood imagination. Leonardo also could have encountered caves and springs while walking through this region of Italy, which could have inspired the landscape in his ***Virgin of the Rocks*** paintings. His earliest landscape is his ***Arno Valley Landscape***, dated 1473, and his subsequent landscapes tended to be located around the Valdarno and Val di Chiana south of Florence, between Arezzo and Cortona.

During the summer of 1502, Leonardo worked for **Cesare Borgia** and lived in a castle overlooking the Ponte a Buriano, which crossed the Arno outside Arezzo. The landscape views in Leonardo's paintings are clearly imaginary, but perhaps the bridge in the ***Mona Lisa*** is reminiscent of Buriano, which Leonardo could have seen while traveling across the Apennines in the service of Borgia. At times, his travels would have

required crossing high-altitude passes similar to that of the Alps, which could have inspired the tall, rocky mountains in many of his paintings, while the eroded, sandstone bluffs called Le Balze, which rise up suddenly in a region between Arezzo and Florence, might have engaged Leonardo's geological interests. These exposed rocks perhaps helped Leonardo formulate his ideas about water erosion, visible in his *Arno Valley Landscape*, where the undulating rings that form the mountains seem to be in a constant state of movement.

In Leonardo's drawings, mainly the series of deluge images, he describes the power of water to shape the land through its rock formations, while in other drawings, for example, a red and white chalk sketch on red paper of snowcapped peaks, his careful observation of the land also allowed him to study depth and atmosphere (c. 1510, Windsor, Royal Library). His *Map of Tuscany and the Chiana Valley*, c. 1502, shows Leonardo's landscape interests also helped form his ability to create some of the earliest aerial view maps, where he extrapolated an aerial view at 90 degrees from a bird's eye view of an approximately 45-degree angle observed while standing on a mountain top. From this mathematical **perspective**, Leonardo was able to create a fairly accurate map of the Valdichiana near Arezzo, where he labeled the rivers and towns to create either a military map for Cesare Borgia or a water study for the Republic of Florence. For Leonardo, water and mountains had the ability to show how nature is formed throughout the years, and they both confirm that through constant movement, the Earth's surface is constantly reformed. *See also* ATMOSPHERIC PERSPECTIVE; CARTOGRAPHY; DÜRER, ALBRECHT; GEOLOGY; LEONARDESCHI; LINEAR PERSPECTIVE; PAINTINGS, PORTRAITS.

LANSDOWNE MADONNA. *See MADONNA OF THE YARNWINDER (LANSDOWNE).*

LAST SUPPER. Leonardo's *Last Supper* is perhaps his most famous work. Commissioned by Duke **Lodovico Sforza**, this wall mural measures 15 by 29 feet and is located in the refectory, or dining area, of the convent of Santa Maria delle Grazie in **Milan** and was part of a larger renovation project planned for the church and convent. Begun in about 1495, the work depicts the Last Supper of Jesus and the 12 apostles, found in the Gospel of John, 13:21. This is the moment when Jesus announces that one of the apostles will betray him, and Leonardo sought to reveal a variety of human emotion and gesture at this moment. The mural was documented as being almost finished in 1497; therefore, thought to have been complete by 1498.

Leonardo did not work in the traditional **fresco** technique of pigments mixed with water painted onto a damp surface; instead he mixed his **colors** with **oil** and painted onto a dry wall to achieve his characteristic **sfumato** and **chiaroscuro** style of atmospheric haziness and shading. Because oil does not soak into damp plaster like water, Leonardo's pigments lay on the surface of the wall and eventually began to flake off. Further damage occurred during World War II, when the monastery was mistakenly bombed in 1943, by Allied forces. An oil-on-canvas full-sized copy made in about 1520, by Leonardo follower **Giampietrino**, reveals how Leonardo's original work must have appeared before its decay.

The mural covers the end wall of the rectangular room that was originally planned as a Sforza family mausoleum and measures 350 inches wide by 180 inches tall. The room was later remodeled into a refectory. The lunettes above were painted with the Sforza coat of arms, while on the opposite wall Giovanni Donato da Montorfano (c. 1460–c. 1502) painted a *Crucifixion* in 1495. Some scholars think Leonardo added members of the Sforza family to the scene, given that they were painted in oil on top of Montorfano's **tempera**.

What makes Leonardo's version of this popular scene unique is that he sought to break the horizontality of the scene by showing the apostles in different states of awareness, grouped together in threes and seated or rising up in an undulating line of emotion. A drawing of the apostles, now in the Accademia in **Venice**, identifies the figures from left to right: Bartholomew, James, the

son of Alphaeus, Andrea, then Judas Iscariot, Peter, and John the Evangelist. Judas pulls away from the group while holding a small bag that could be the money he received for his betrayal. Jesus appears in the center of the table in front of the middle of three windows, which provide a trio of **light** sources for the room, and to Christ's left are Thomas, James the Greater, Philip in a group of three, then Matthew, Jude Thaddeus, and Simon. The gestures and poses relate to stories of the apostles; for example, Thomas looks incredulous at Christ's announcement. The figures sit along a long table facing the viewer, while the table is covered with a white cloth, bread, and platters of food. Judas knocks over a salt cellar. The floor has lines that recede back into space, while the walls feature windows and tapestries that also recede back, with orthogonal lines that lead the viewer's eyes to Christ's head. There we see Christ holding his arms out on the table to form a triangle. The apostles include four groups of three, and the number three as well as triangular composition, are repeated throughout the work to provide a rich language of numerical symbolism specific to the **Renaissance**.

Indeed, the *Last Supper* is one of Leonardo's clearest examples of his translation of mathematical interests and optical studies into a work of art. In addition to the repetition of three, which refers to the Holy Trinity, the Fibonacci series is alluded to in the number of figures and objects in the room: 1, 1, 2, 3, 5, 8, and 13. Certainly Leonardo was likely inspired by the mathematical studies of his friend, **Fazio Cardano**, in Milan, whose son Girolamo mentioned seeing the work as a boy before the colors started to deteriorate. **Giorgio Vasari** also lamented its deteriorated state, and in the mid-1600s, a door was cut through the wall, damaging the bottom portion of the mural. Later, the mural was varnished and further damaged with curtains and humidity. Despite this, Leonardo's *Last Supper* remains one of the most famous paintings in art history and is frequently referenced in popular literature, modern art, and film. *See also* BROWN, DAN; CATHOLICISM; MATHEMATICS; PACIOLI, LUCA; PAINTINGS.

LATIN. Latin was the Indo-European language of Latium, which was spoken in the area of Central Italy in antiquity. It became the main language of the Roman Empire and eventually developed into the Romance languages of Italian, Spanish, and French, among others. Latin developed throughout the years from

Leonardo da Vinci, *Last Supper*, 1495–8, 15 x 29 feet, tempera and oil on gesso, Milan, Santa Maria delle Grazie.

Old Latin and its colloquial dialect, called the Vulgar Latin, to Classical Latin and Late Latin. After the fall of the Roman Empire Latin was the language of the Catholic Church through the **Renaissance**. The Vulgate, a late 4th-century Bible written in Latin and attributed in its translation to Saint Jerome, was considered the official version of the Bible through the 1500s, and Latin was also used for scholarly and formal writing, for example, literature and legal documents. Latin came to be the international academic language, spoken throughout Europe and taught in the universities first formed in the late Middle Ages, while in the Renaissance, humanist scholars continued to speak and translate Latin.

Despite this, most people remained illiterate and spoke a local vernacular, and could not read or write. These vernacular tongues derived from the Vulgar Latin and are sometimes described as dialects of Italian, although most are actually classified as different languages. What became the standard Italian language originated in Tuscany in the 1200s, when writers from Central Italy began to write prose and poetry in their vernacular, and by the 1300s, Dante Alighieri (c. 1265–1321) was writing in a Tuscan dialect that was widely read throughout the Italic Peninsula and developed into a standardized dialect we consider the official modern Italian language.

By the 1400s, **Florence** had begun to dominate the peninsula, not only in prosperity and military might, but also in their cultivation of high culture in the arts and sciences, and the use of their language was the auditory expression of their dominance By the 1500s, the Venetian dialect was being used in commerce and the Genoese dialect in sea travel, while the Tuscan dialect became the official language in the courts of the Italic Peninsula. Nevertheless, Latin remained the language of the intellect in the Renaissance; it was the marker of the educated class. Many texts were translated from ancient Greek into Latin during the Renaissance, including Florentine humanist Leonardo Bruni's (c. 1370–1444) version of the Aristotelian *Economics*, which was printed in 70 editions through the 1500s, while his translations of Aristotle's *Politics* and *Nicomachean Ethics* were also widely read. Humanists sought to maintain Latin as an important expression of the classical world; therefore, Latin remained the primary language for official documents through the 1600s.

This historical backdrop explains why many scholars have found it important to mention that Leonardo was not formally educated and never learned Greek or Latin. Thus, although he is considered one of the greatest geniuses of the Renaissance, he was never a humanist scholar. His illegitimate background prevented him from following in his father's footsteps as a notary, where he would have received such an education. Instead, his father placed him into the workshop of the most prominent artist in Florence at the time, **Andrea del Verrocchio**, where Leonardo developed an interest in the keen observation of the natural world. He also sought out intellectual pursuits, however, and owned several Latin books, studied Latin on his own, and wrote simple Latin phrases in his **notebooks**. Perhaps his difficulty with this language acquisition motivated him in championing the idea that one must not rely solely on the ideas of ancient scholars, but those ideas need to be tested through careful scientific observation. Similarly, Leonardo received no formal education in mathematics, but he made connections with many mathematicians throughout his life, one of whom was **Luca Pacioli**, with whom he collaborated on a treatise on **geometry**. In this way, Leonardo came to be known for his exacting pictorial realism, scientific observations, and many **inventions** by following the path of the practicing artist and scientist rather than that of the humanist scholar. *See also* CATHOLICISM, CLASSICISM; HUMANISM; VENICE.

LEDA AND THE SWAN. Leonardo was interested in the theme of Leda and made several sketches of this classical nude female while he was in **Milan** where he also made sketches of the swans swimming in the Sforza family castle moat. In 1625, Cassiano del Pozzo described a painting of Leda in the royal collection in Fontainebleau that could be a lost painting of this subject by Leonardo. Here, Cassiano described the nude female standing

in contrapposto in a landscape next to a swan, while two pairs of infants are hatching out of eggs at her feet. Cassiano also mentioned that the wood panels were split and separating, and this painting is not extant today.

Leonardo began his studies of Leda in 1504, and three extant **drawings** (in the Devonshire Collection in Chatsworth, the Museum Boijmans van Beuningen in Rotterdam, and the Royal Library in Windsor), which were widely copied, show his original plans for a painting that was either never finished or is lost. In 1506, **Raphael** made a sketch of Leda, while several of Leonardo's followers painted variations on her, perhaps modeled after Leonardo's two lost cartoons for the painting, one of which shows Leda kneeling on the ground, as seen in a painting by **Giampietrino** (Kassel, State Museum), while the other depicts her standing. The standing Leda became the more famous version, known today in numerous copies, including the earliest one by **Francesco Melzi**, one by **Fernando Yáñez de la Almedina**, and the best example by **Cesare da Sesto**. A variant on this subject depicts Venus and Cupid, as seen in a version by Giampietrino. *See also* CLASSICISM, LEONARDESCHI.

LEFT-HANDED. Leonardo is documented as being left-handed, and he wrote backward in a technique called mirror writing. Throughout history, right-hand dominance has ranged between 70 to 90 percent of the population, while there has been a consistent bias against left-handedness. Today, left-handedness is considered preferable for some activities, including many types of sports, but right-handedness remains the norm and is the preferred industry standard for tools, utensils, and furnishings. Studies of cognitive differences between the two continue to be inconclusive. Yet, many think of left-handed people as having superior spatial awareness, superior language skills, more sophisticated emotions, and a higher level of creativity, and with a slight preference for **music** and mathematical abilities.

Being left-handed was a distinct disadvantage throughout history, however, primarily because it was considered evil within the Catholic Church. The blessed sit at the right hand of Christ, while the sinners fall from his left, or *sinistra*, or "sinister," side. Even through the 20th century, left handed children were trained to write with their right hand despite new scientific studies on hand dominance and the bilateral brain suggesting there is no moral difference between the two. It is interesting to think that had Leonardo followed his father's footsteps as a notary, he would perhaps have been trained to write with his right hand, but since he was prohibited from entering that profession due to his illegitimate birth, his father placed him in the workshop of **Andrea del Verrocchio**, where being left-handed was not necessarily a disadvantage. Instead, shading and shadowing with the left hand provided subtle differences in design that could have been advantageous for drawing and painting; therefore, Leonardo's mirror writing was perhaps the result of his lack of a formal education, where his writing would have been "corrected."

Leonardo became famous for his mirror writing, and although we link this to his left-handedness, it is an inherited condition found in right-handed people as well and is thought to be the result of an atypical organization of language across both sides of the brain. Despite these scientific studies, some scholars continue to suggest that Leonardo sought to hide his ideas with this simple cipher, an idea that has not been substantiated in any of his work but holds a lot of traction in historical fiction novels about him. More recent studies have shown that mirror writing is surprisingly more common among children than acknowledged, and it is likely the result of a more fluid understanding of letters as objects that rotate in space. Leonardo clearly had a superior understanding of how objects are configured in space, and he could extrapolate their appearance from different rotations, leading to great advances in **cartography** and **geometry**. This intuitive skill normally dissipates as children grow up, but clearly it remained important to how Leonardo understood the world throughout his life. *See also* CATHOLICISM; MATHEMATICS; NOTEBOOKS.

LENS GRINDER. *See* ANAMORPHOSIS; INVENTIONS; LIGHT.

LEO X (1475–1521). In 1513, Leonardo was invited to **Rome** by Giuliano de' **Medici**, the brother of the newly elected Pope Leo X, and he spent three years there, where he lived in an apartment in the Palazzo Belvedere with his students, **Salaì** and **Francesco Melzi**. Leo X was born Giovanni di Lorenzo, the second son of Lorenzo de' Medici, and ruled as pope from 1513 until his death in 1521. He is best-known for continuing the construction of the Basilica of Saint Peter's, begun under Pope Julius II, who died in 1513. Much of the work was funded through indulgences, a practice that was challenged by Martin Luther after his visit to Rome in 1511. Leo's papal bull of 1520, called the *Exsurge Domine*, condemned Martin Luther, which led to the Protestant Reformation.

During this time, Leonardo was involved in improving the city infrastructure with **hydraulics** and architectural plans, and he tried to create a solar reflector in the shape of a round, parabolic disk that could amplify the heating process of water to dye fabrics more quickly. This invention, never realized, would have benefited the Medici family dye industry. Meanwhile, **Michelangelo** had completed the Sistine Ceiling, and **Raphael** was continuing his work in the papal apartments. Leo X was known as a patron of the arts and promoted the study of classical antiquity. *See also* BRAMANTE, DONATO; CLASSICISM; SOLAR POWER; WATER STUDIES.

LEONARDESCHI. Leonardo influenced many artists, beginning with his students, collaborators, and immediate followers. His best-known students include **Giovanni Antonio Boltraffio**, **Salaì**, **Marco d'Oggiono**, and **Francesco Melzi**, while he also trained **Giovanni Ambrogio de Predis**, **Bernardino de' Conti**, and Andrea Solario (1460–1524). He typically maintained a studio with six students, while other artists, described as "Leonardeschi," included painters who worked in a realistic style characterized by a **monochromatic** palette of **oil** pigments, a consistent use of **sfumato** to soften the edges of figures and objects with a diffuse, golden **light**, a subtle use of **chiaroscuro**, or light and dark contrasts, and a vast, atmospheric landscape background. Leonardo's figures engage with the viewer and move in space, following scientific principles of **perspective** and **optics**. His style was continued by his students after his death, and it spread to parts of Southern Italy and Spain, while some Flemish artists also adopted his sfumato technique. Artists, one of whom was **Raphael**, copied his compositions in similar subjects from both his **paintings** and **drawings**, and some of Leonardo's lost or damaged works are best known in later copies. During the next two centuries, Leonardo's artistic principles and unique style were incorporated into the canon of later **Renaissance** and Baroque painting of the 1500s and 1600s. *See also* ATMOSPHERIC PERSPECTIVE, LANDSCAPES; MILAN.

LIGHT. The study of light was an essential part of an artist's education in the **Renaissance**, when new **colors** were introduced and the modeling of figures through shading and shadowing allowed for a heightened realism, the prevailing style of Renaissance painting. Artists studied how light falls on objects, changes throughout the day, affects color, and reveals objects, while the absence of light conceals them in a technique called **chiaroscuro**. Leonardo wrote in his **notebooks** that there are four different kinds of light that illuminates objects: diffuse light, direct light, light that is reflected off objects, and light that passes through objects. Leonardo's study of diffuse light provided him with his characteristic **sfumato**, or atmospheric haziness, which surrounds his objects with a soft lighting, while his study of direct lighting allowed his painted objects to show the direction of the light source to create pictorial depth. Leonardo also experimented with **oil** pigments that could reflect light to create a shimmering surface, while his careful building of color allowed him to depict thin linen veils and other translucent materials.

Ultimately, the study of light allowed artists like Leonardo to create effective gradations of color to model figures in such a way that they appear three-dimensional on a two-dimensional surface and show depth by using brighter foreground colors and less contrasting colors in the background. Leonardo's careful brushwork also allowed him to create subtle

gradations of color to give the appearance of natural light. Leonardo's ***Mona Lisa*** is an effective summary of his studies of light. Here we see Lisa posing in a hazy atmosphere, with her skin illuminated by a golden light. Her face is softly modeled with subtle contrasts between light and dark, and her clothing is muted in color but revealed through light and dark color contrasts that form the drapery folds of her dress.

In addition to the observation of light, Leonardo sought to invent tools that could capture or manipulate light, for example, his grinding machines for either mirrors or lens, found sketched in his ***Codex Atlanticus***. One lens grinder was designed for grinding small concave mirrors, while another larger machine could grind larger lenses. On fol. 59r, there is a telescope and a study of light reflecting off a convex mirror. These tools could have been used to create a prototype of a pinhole camera, where light would shine through a small hole into a dark room, refracting through a lens and projecting an image on the opposite wall that originates outside the hole. The inverted image could then be reoriented with a mirror. A famous painting that displays the use of a convex mirror is Jan van Eyck's (c. 1390–1441) *Arnolfini Wedding Portrait*, done in Bruges in 1434. In Italy, **Leon Battista Alberti**, in his treatise *De Pictura*, written in the same decade, discussed how mirrors can either deform or correct things found in nature. *See also* ANAMORPHOSIS; BRUNELLESCHI, FILIPPO; FLORENCE, MATHEMATICS, OPTICS.

LINEAR PERSPECTIVE By the early 1400s, **Filippo Brunelleschi** and **Leon Battista Alberti** had codified a system of mathematical perspective whereby orthogonal lines could be measured beginning at one fixed point and angling inward toward a vanishing point to converge at the horizon line. While Brunelleschi experimented with perspective to make scale architectural **drawings**, Alberti codified these principles in his treatise on painting called *Della Pittura*, written in 1436.

Like many other artists of the later 1400s, Leonardo recognized the limitations of Alberti's mathematical perspective, also called one-point perspective. Leonardo's drawing for his unfinished painting ***Adoration of the Magi*** (pen and ink with silverpoint and white on paper, 163 x 290 mm., **Florence**, Uffizi Gallery) shows a more advanced perspective that suggests more movement, where the space is measured in a grid with lines that recede back toward the center horizon. Two sets of stairs appear on the viewer's left, with one smaller than the other to show its farther distance from the viewer, while a lightly sketched pitched roof suggests a room covering. In other early Florentine **paintings**, for instance, his ***Annunciation***, Leonardo contrasted closed and open spaces that recede back into the picture plane. Soon Leonardo expanded Alberti's one-point perspective to a three-point perspective model, where lines converge at three different points across the painting to suggest movement as the viewer walks between multiple viewpoints. Through Leonardo's studies of **optics** and his careful observations of the physical characteristics of the eye, he also understood that perspective included the diminution of the object, a change in color as the object appears farther away, and less visual clarity as the object seems to disappear in the distance.

Leonardo also experimented with various lenses and mirrors in **Milan** through the 1480s, using them to create a curved or distorted perspective, called an **anamorphosis**, whereby an image appears distorted when viewed frontally, but when the image is viewed from an oblique angle, the distortion disappears. The first-known anamorphic drawing is a sketch of Leonardo's eye found in the ***Codex Atlanticus***, fol. 98r, c. 1485, where the eye is stretched out into a long oval, yet appears shortened into its correct shape when the drawing is viewed from a sharp angle. Clearly, Leonardo understood the paradox between how things are and how they appear, which he sought to explain mathematically. *See also* ATMOSPHERIC PERSPECTIVE; LIGHT, MASACCIO, MATHEMATICS.

LIPHART, KARL EDUARD VON (1808–1891). Baron Karl von Liphart was an art collector raised in the sprawling Raadi Manor outside Tartu, Estonia, whose aristocratic family was involved in the patronage of arts

and **music** of Estonia, Russia, and Germany. Liphart founded the Estonian Naturalists' Society in 1853, before moving to **Florence** in 1862, where he spent the rest of his life amassing an important collection of Italian **Renaissance paintings**, while becoming known as a respected art connoisseur. In 1867, an ***Annunciation*** painting arrived at the Uffizi Gallery in Florence from the monastery of San Bartolomeo outside Florence and was attributed to **Domenico Ghirlandaio**, who apprenticed in **Andrea del Verrocchio**'s studio at the same time as Leonardo. Two years later, Liphart identified the painting as an early work by Leonardo, an attribution that remains largely accepted today. Liphart lived at the center of the art culture in Florence and was in communication with the major art historians in Europe, while his son, Ernst Friedrich von Liphart, raised in Florence, later became a painter and curator of the Hermitage Museum in Saint Petersburg. *See also* BERENSON, BERNARD; BODE, WILHELM VON; FREY, KARL OTTO; MCCURDY, EDWARD ALEXANDER COLES; MORELLI, GIOVANNI; MUSEUMS; WAAGEN, GUSTAV FRIEDRICH.

LIPPI, FILIPPO. *See* BOTTICELLI, SANDRO; FLORENCE.

LIRA DI BRACCIO. *See* MUSIC.

LLANOS, HERNANDO DE LOS (active 1505–1525). This Spanish painter from Cuenca was introduced to Leonardo's **paintings** while in Italy. Although little is known of this artist, Llanos, together with Spanish painter **Fernando Yáñez de la Almedina**, who he likely met in Valencia, traveled to **Florence** to assist Leonardo on his unfinished ***Battle of Anghiari*** mural. His later Spanish work reflects this influence, as seen in his ***Madonna of the Yarnwinder*** in the Museo de Bellas Artes in Murcia, from a subject introduced by Leonardo, to his *Resurrection of Christ*, an **oil**-on-panel painting in the Cathedral of Valencia that reveals two figures on the viewer's left with grimacing faces similar to Leonardo's **caricatures** done for the *Battle of Anghiari*. *See also* LEONARDESCHI.

LODI, GIOVANNI AGOSTINO DA (c. 1470–c. 1525). Giovanni Agostino da Lodi was previously called the Pseudo Boccaccino until his oeuvre was more fully established in the mid-20th century. He worked in both **Venice** and **Milan** in the first decades of the 1500s, in the circle of Bramantino and the style of Leonardo, which he likely learned while studying with Leonardo's student, **Marco d'Oggiono**, in Milan. His *Christ Washing the Feet of the Apostles*, from c. 1500 (Venice, Accademia), reveals Leonardo's characteristic **sfumato**, together with more sharply delineated drapery in the Flemish style, while his Madonna and Child paintings reflect a style and composition similar to the work of Venetian painter Giovanni Bellini (c. 1430–1516). *See also* LEONARDESCHI.

LOMAZZO, GIOVANNI PAOLO (1538–1592). Italian Mannerist painter Giovanni Lomazzo was born in **Milan** and wrote two theoretical treatises on art, including *Trattato dell'arte della pittura, scoltura et architettura*, published in Milan in 1584, where he sought to define an aesthetic theory of art through individual artist styles rather than their biographical experiences, as **Giorgio Vasari** had done in his earlier publication from 1550. Lomazzo described Leonardo's painting technique and argued that, since Leonardo was such a perfectionist, he was never able to complete his **paintings** because he always found flaws that other people could not see. Lomazzo mentioned a few of Leonardo's paintings, including his ***Mona Lisa*** and a separate painting called *La Gioconda*, which has led scholars to think Leonardo must have painted two versions of this famous portrait. Later scholars have confirmed Lomazzo's accuracy in other historical notations, so this idea is certainly credible.

As a friend of Leonardo's student and heir, **Francesco Melzi**, Lomazzo was familiar with Leonardo's theories on art and cited him frequently in his own treatise, where he included Leonardo's famous comparison between the art of painting and **sculpture**, and his argument for the superiority of painting. Leonardo's unpublished ***Treatise on Painting***, the *Codex Urbinas*, in the Vatican (lat. 1270), does not

include this discussion, however, so perhaps it was written in the lost folios Lomazzo had seen in Melzi's collection. Indeed, this could have been the inspiration for Lomazzo's invented dialogue between Leonardo and Greek sculptor Phidias, written in his *Book of Dreams* from 1563, known today in autograph copy in the British Library, London (add. mss. 12196), which addresses a broad variety of topics, from the natural sciences to **music** and art. This work laid the foundation for Lomazzo's more focused study on the arts, published in 1584, and another treatise specifically on painting in 1590. *See also* CELLINI, BENVENUTO.

LUCAN PORTRAIT OF LEONARDO. This painting, discovered in Italy in 2008, is a portrait head of an elderly bearded man done on **oil** and **tempera** on wood (17 x 24 in., Museo delle Antiche Genti d. Lucania, Vaglio Basilicata). The man wears the soft velvet cap of a scholar and artist with a white feather tucked along the top, and has long, flowing hair that blends into a long beard, both of which reach down to his torso. The portrait is cut off just below the man's shoulders to reveal the top of a black cape, while he poses frontally but with his head tilted slightly to the viewer's right to show more depth, and his brow is slightly furrowed to suggest emotion. The painting was named the Lucan portrait after it was discovered in a private home in Basilicata, which was called Lucania in antiquity. The man in the painting seems to resemble Leonardo, as seen in the red chalk portrait drawing of Leonardo attributed to his student, **Francesco Melzi** (after 1510, 275 x 190 mm., red chalk on paper, Windsor, Royal Library, WGA 14795), where Leonardo appears as an older man with a long beard, which was highly uncharacteristic of **Renaissance** fashion and thus would have been unusual.

Another red chalk drawing, considered a self-portrait of Leonardo at age 60, is a frontally posed image from c. 1510 in the Biblioteca Reale in Turin, which resembles the Lucan portrait. While some scholars attribute the painting to Leonardo because of an inscription on the back that claims it is a "picture of me (PINXIT MEA)" done in **Latin** mirror writing, most scholars consider it a work of a minor artist, perhaps Cristofano dell'Altissimo, who made copies of some of the **portraits** owned by Renaissance scholar **Paolo Giovio** in a series called the Giovio Series, which is not extant today but is known in copies made for Cosimo de' **Medici**, now in the Uffizi Gallery in **Florence**. Further scientific research has shown the work to be from the early 1500s, but while a group of scholars continue to confirm an attribution to Leonardo through forensic analysis, most scholars consider the work one of the many later portraits of Leonardo done as testament to his enduring fame. *See also* DRAWINGS; *PORTRAIT OF A MAN IN RED CHALK.*

LUINI, BERNARDINO (c. 1480–1532). Bernardino de Scapis Luini is one of the few artists who worked directly with Leonardo, and some of his early works have been previously attributed to Leonardo. Born in a small town in Lombardy called Runo, near the town of Luino on the east side of Lago Maggiore, Luini moved to **Milan** in 1500, perhaps training in the studio of Ambrogio Bergognone (c. 1453–1523). After a period of travel, he returned to Milan and established a successful workshop to become one of the best-known Lombard painters of the **Renaissance**. It was during this era, the middle period of his career, that his work was most influenced by Leonardo, and several of his **paintings**, notably his *Christ among the Doctors* and *Virgin and Child with Saint John the Baptist*, are based on Leonardo's compositions. The *Virgin and Child with Saint John the Baptist*, from c. 1510 (London, National Gallery), depicts the Virgin seated on the ground, flanked by the two infants, who kneel, pose, and gesture similar to the infants in Leonardo's painting of the same subject. While Luini used Leonardo's **chiaroscuro** and rocky landscape background, his facial features are slightly different, and his **colors** are brighter. *See also* LEONARDESCHI.

M

MACHIAVELLI, NICCOLÒ (1469–1527). Leonardo met Niccolò Machiavelli after he returned to **Florence** in 1503 and began to paint the ***Battle of Anghiari*** for the Salone dei Cinquecento in the Palazzo Vecchio. This large room was the meeting hall for the Grand Council, and from 1498–1512, Machiavelli was a government official who cosigned Leonardo's work contract for the mural. Machiavelli is known for his work in helping to define modern political science at a time when political power was constantly evolving and sometimes chaotic. Indeed he rose in authority when the **Medici** family went into exile; the Republic was restored in Florence by **Piero Soderini**, who was elected as gonfalonier in 1502; and **Girolamo Savonarola** was executed as a traitor.

Soon after Leonardo began the mural, Soderini asked Leonardo to examine the possibility of diverting the Arno River, and Machiavelli, in his role as secretary of the Florentine government military council, became interested in this project and wrote many directives concerning its completion. The plan was to divert the river to cut off the water supply for the rival town of Pisa, but it was eventually canceled after it was deemed a failure. Nonetheless, during this time Leonardo introduced Machiavelli to the applied scientific process, which is thought to have influenced Machiavelli's later theories on the rational order of statehood. In 1512, Soderini resigned as gonfalonier, and the Medici returned to power. Machiavelli, accused of political conspiracy, was allowed to return to his villa, where he spent the rest of his life writing political treatises and literary works, notably *The Prince,* where he describes an allusion to the "river of fortune," which was inspired by Leonardo's river project. *See also* BORGIA, CESARE, ENGINEERING; INVENTIONS.

MADONNA AND CHILD WITH THE POMEGRANATE. *See DREYFUS MADONNA.*

MADONNA LITTA. The *Madonna Litta,* generally attributed to Leonardo, depicts a half-length Virgin nursing the Christ Child. It belonged to the noble Litta family of **Milan.** Done in **tempera** paint on wood panel, the painting, measuring 17 x 13 inches, has been transferred to canvas and is now located in the Hermitage Museum in St. Petersburg. It dates to c. 1490, during the time Leonardo worked in Milan. This *Madonna lactans,* or nursing Madonna, is unique in Leonardo's oeuvre but was a common theme in **Renaissance** Italy, where the Virgin's milk symbolized her sacrifice, much like how Christ's blood sacrifice provided salvation. The Virgin appears to be standing at an angle to the viewer in a dark room lit by two arched windows that flank the Virgin's head and depict distant mountains in a soft azurite blue. The Virgin is dressed in elegant clothing, while her hair is wrapped in a modest headscarf. The act of nursing the Christ Child also symbolized her humility and maternal devotion at a time in Renaissance **Florence** when wealthy children were sent to live with a wet nurse until the age of two.

The attribution to Leonardo has been contested. Yet, the soft **sfumato** and realistic

modeling of the Virgin's face, set at an angle to the viewer, clearly demonstrates the style of Leonardo, which could also be found in the work of his Lombard followers, for example, **Marco d'Oggiono** or **Giovanni Antonio Boltraffio**. It is thought that Leonardo began the painting during his first Florentine period, in about 1478, because similar Madonna and Child images were popular in Florence during this time. The Christ Child holds a goldfinch, which was a popular symbol of his sacrifice, seen also in the Madonna and Child **paintings** of **Raphael** done in Florence. It is assumed he would have taken it to Milan, where one of his students could have finished it; however, some scholars have suggested that stylistic analysis demonstrates the painting was completed by one artist instead of two.

In addition, several preparatory **drawings** exist by Leonardo, including a metal point pen on gray paper titled *Head of a Young Woman in Near Profile* (Paris, Louvre Museum, Cabinet des dessins, Codex Vallardi 2376 recto), which was copied by several of Leonardo's students, while a painting of a lactating Madonna attributed to Leonardo was described by Marcantonio Michiel in **Venice** in 1543. Aside from this one historical notation, the provenance of the painting is not known prior to 1784, when it was bought by Milanese nobleman Alberico di Belgioioso. It then entered the Litta collection in 1813, and in 1865, Tsar Alexander II purchased the painting for the Hermitage Museum in St. Petersburg. *See also* CATHOLICISM; MUSEUMS.

MADONNA OF THE CARNATION. This small devotional painting of a seated Virgin holding the Christ Child was a popular subject in **Florence** in the late 1400s and early 1500s. It is **tempera** and **oil** on poplar panel, measures 24.4 x 18.7 inches, dates c. 1475–1478, and is located in the Alte Pinakothek in Munich. The painting was first attributed to **Andrea del Verrocchio** and is now generally attributed to Leonardo but with overpainting perhaps completed by a Flemish artist. The subject shows the Madonna dressed as a noble woman in a sleeveless blue dress held together with a large stone brooch over a long-sleeved red undergarment. Her dark blond hair is braided and tied up into a discreet veil, while gentle curls frame her round face. The Virgin looks down at the squirming, chubby Christ Child, who is seated nude on a brown velvet cushion. She offers him a single red carnation, a symbol of her love and sacrifice. The Child reaches out toward the flower, but his eyes look out toward the viewer. A translucent glass flower vase sits on the opposite side of the Virgin, while paired arched windows flank the Virgin on the wall behind her and show a dream-like landscape of hills and distant jagged mountains unlike those found in Central Italy.

Thought to be one of Leonardo's first independent **paintings**, some scholars, for instance, Pietro Marani, have suggested that Verrocchio perhaps contributed the original design based on the fact that a related drawing of the Christ Child, now in the Uffizi Gallery in Florence, is attributed to **Lorenzo di Credi**, another student of Verrocchio, and that same Christ Child appears in a painting of the same subject done in the workshop of Ridolfo Ghirlandaio (1483–1561), now in the Walter's Art Gallery in Baltimore, Maryland. Clearly, designs, figures, studies, and sketches were shared among artists working in the same studio, and oftentimes these artists painted in a similar style, which continues to make attributions a challenge. *See also* CATHOLICISM.

MADONNA OF THE ROCKS. *See VIRGIN OF THE ROCKS.*

MADONNA OF THE YARNWINDER (BUCCLEUCH). This Madonna and Child is one of two **paintings** of this subject sometimes attributed to Leonardo. It is an **oil**-on-walnut panel measuring 19.25 x 14.5 inches, located in the Scottish National Gallery in Edinburgh, on long-term loan from the Buccleuch family. This painting was in the international news recently when, in 2003, it was stolen from the family's Drumlanrig Castle and returned in a dramatic and complex sting operation.

Leonardo is documented as having worked on this subject in **Florence** in 1501, and the painting was completed in 1507, and sent to its owner, Florimond Robertet, secretary to King Louis XII of France. These documents

refer to either this painting or the *Lansdowne* version. Here we see a seated Madonna holding a squirming Christ Child on her lap. The scene is painted in a restricted, dark palette, with soft modeling characteristic of Leonardo's **sfumato**, and the background, with its rocky mountains and water, which extends far into the distance, is similar to Leonardo's landscape views. Here the Christ Child contemplates the spoke of a yarnwinder, attached to a second spoke to create the shape of a cross. Thus, this domestic object refers both to the domestic image of the Virgin, while anticipating the idea of Christ's crucifixion. This is a variation on the theme of the Virgin sewing or knitting, which is also an act of creation. Christ grasps the wood of the yarnwinder with both hands, and as the Virgin reaches around to hold Christ, the wood presses into her flesh. Her right hand reveals a unique pose, angled to show her palm from below, similar to her gesture in the ***Virgin of the Rocks***.

Leonardo is thought to have completed the underdrawing, perhaps while in **Milan** prior to 1499, since that is where he used walnut wood. He could have then brought the unfinished panel back to Florence, where it was finished in his workshop. Scientific studies of the underdrawing reveal that in both versions of this painting, Saint Joseph appears making a baby walker, while another woman and child, likely Saint Elizabeth and John the Baptist, are similar to Leonardo's ***Virgin and Child with Saint Anne and Saint John the Baptist***. The underdrawing also shows an ox, a bridge, and other architectural elements, revealing Leonardo's experimentation with different ways of presenting the landscape background. These elements are similar in the *Lansdowne* version and appear in several copies of this painting, which suggests that the underdrawing was made available for copies before the painting was finished. Ultimately, the Madonna and Child seated in a landscape anticipated **Raphael's** paintings of the same subject done in Florence in the early 1500s. *See also* CATHOLICISM, LANDSCAPES; MUSEUMS.

MADONNA OF THE YARNWINDER (LANSDOWNE). This Madonna and Child painting is an **oil**-on-wood panel painting later transferred to canvas, then back to wood. It measures 19.7 x 14.3 inches and is named after the Marquesses of Lansdowne family but is now in a private collection in the United States. Like the *Buccleuch* version, this painting is thought to have been prepared by Leonardo, since the underdrawing is characteristic of his working process and similar to the underdrawing of the *Buccleuch* painting. Perhaps both were completed in Leonardo's workshop at the same time, although the *Buccleuch* painting is considered the primary version based on stylistic analysis. A letter written in 1501, from Fra Pietro da Novellara of the Carmeline Order in **Florence** to Isabella d'Este of **Mantua**, mentions that Leonardo was working on a painting of this subject, which could refer to either version. Fra Pietro described the work, a rare contemporary description of one of Leonardo's **paintings**, and he further explained that Leonardo had turned his attention to some mathematical studies, which would explain why the work was completed by Leonardo's workshop.

The compositions are similar, and both depict a seated Virgin holding the infant Christ in front of her. Christ turns away from his mother and gazes at the spoke of a yarnwinder in the shape of a cross. Christ clutches the cross, his face in careful contemplation. Here, the Virgin's right hand, gesturing downward, reveals an excellent example of depth where the viewer sees her palm facing downward. Meanwhile, an imaginary landscape with rocky cliffs and a meandering river extends back into a blue distance similar to Leonardo's ***Mona Lisa***. While the *Buccleuch* version is painted in dark earth tones, this version has a brighter palette of blues and yellows, with a more distinct use of **atmospheric perspective**. Ultimately, it is unclear whether the patron, Florimond Robertet, secretary to King Louis XII of France, ever received the painting, although in 1507, Francesco Pandolfini reported in Florence that he received a small painting by Leonardo destined for the French court.

Meanwhile, an inventory made after Leonardo's death noted a similar painting in the collection of Leonardo's student, **Salai**, but provenance history is unclear for both versions

of the painting prior to the 1700s. Nonetheless, such scholars as **Martin Kemp** have suggested through stylistic analysis that the *Buccleuch Madonna* was the version sent to Robertet, while this version remained in Leonardo's workshop. In 1908, this painting was purchased by E. Gimpel & Wildenstein, and art connoisseur **Bernard Berenson** established an attribution to Il Sodoma (1477–1549), who worked in Siena, but acknowledged it was perhaps based on a cartoon by Leonardo. In 1930, after the first x-ray examination, the painting was reattributed to Leonardo and his Milanese workshop. Forty versions of the painting exist today, many done by Leonardo's students or followers, notably the exceptional version from c. 1510, in the Louvre, which maintains a similar composition to the finished paintings, to a version by Lombard painter Martino Piazza da Lodi (c. 1475–1523), now in the Galleria Nazionale d'Arte Antica in **Rome**, which includes the figures from Leonardo's underdrawing, in addition to a number of versions made by Flemish artists who trained in Florence during the **Renaissance**, for instance, a version by Cornelis van Cleve (1520–1567), now in a private collection. *See also* CATHOLICISM.

MADRID CODICES. This collection of drawings consists of two parchment manuscripts by Leonardo, the first completed in the 1490s, when Leonardo was in **Milan**, and the second done in 1503–1505, when Leonardo was in **Rome** and **Florence.** The two manuscripts were gathered together by Leonardo's student, **Francesco Melzi**, after Leonardo's death, and upon Melzi's death, his son, Orazio, sold them to Italian sculptor Pompeo Leoni (1533–1608), who brought them to Spain while working in the service of Philip II. They are sometimes called the *Madrid Codices* I and II because they were discovered in the National Library of Spain in Madrid in 1965, by Dr. Jules Piccus from the University of Massachusetts. The Spanish provenance of the notebook pages dates back to the late 1500s, when Leoni brought them to Spain while working for King Philip II, and they eventually came into the collection of noble humanist scholar Juan de Espina, after which they ended up in the monastic library of the Escorial before being transferred, along with the royal library collection at the Biblioteca Real, to the Biblioteca Nacional in Spain.

The first codex (Ms. 8937) consists of 192 folios, about 8.5 x 5.7 inches in size, stitched into a Moroccan red leather volume that contains studies of mechanics, with drawings of gears and various inventions done by Leonardo in the mid-1490s, while working in Milan under the patronage of **Lodovico Sforza.** It is considered the first and most comprehensive treatise of mechanics in the **Renaissance.** The second codex (Ms. 8936) is a similarly sized volume of 158 folios bound in Moroccan red leather that features **geometry** studies. Unlike the ***Codex Atlanticus***, which is a miscellaneous collection of folios assembled after Leonardo's death, these codices were assembled by Leonardo and are therefore two cohesive volumes that are largely intact today, except for 16 folios missing from the first volume. In addition to Leonardo's studies of **mathematics** and mechanics with notes on **engineering,** this first codex includes a list of 116 books Leonardo had been consulting while in Milan. Leonardo never learned **Latin;** therefore, his knowledge of antiquity derived from books in translation, but he did own several Latin grammar books listed in this notebook. These volumes are particularly important because they are heavily annotated with Leonardo's textual descriptions of such things as his improved ball bearings and gears, which accompany his mechanical illustrations, demonstrating both his artistic skills and understanding of basic engineering principles. The second volume also includes drawings and maps of the Arno River diversion project, as well as plans for the Sforza equestrian monument. *See also* ADDING MACHINE; NOTEBOOKS, SCULPTURE.

MAGLIABECHIANO. *See* ANONIMO GADDIANO.

MAGNI, CESARE (c. 1495–1534). Little is known of Lombard painter Cesare Magni from **Milan,** except that he spent his entire life in Milan and was a follower of **Cesare da Sesto.** His painting *Holy Family with St. Elizabeth and the Baptist* (c. 1530, Attingham Park, England, National Trust) features a composition made

popular by Leonardo, and he made a copy of Leonardo's ***Last Supper*** (Milan, Pinacoteca di Brera). Copies of the *Last Supper* are particularly important because they have helped restorers reconstruct parts of Leonardo's now-damaged original work. *See also* LEONARDESCHI, PAINTINGS.

MANTEGNA, ANDREA (c. 1431–1506). Italian **Renaissance** painter and antiquarian Andrea Mantegna was a generation older than Leonardo and instrumental in bringing classical archaeology to the arts. He was also interested in the depiction of a dramatic **perspective** in his **paintings**. Mantegna was born in a small town outside Padua, in the Republic of **Venice**, and he was related by marriage to Jacopo Bellini (c. 1400–c. 1470), the founder of Renaissance painting in Venice. He first apprenticed with Paduan painter Francesco Squarcione (c. 1395–1468), a collector of Roman antiquities who had a large studio and trained students from throughout Italy. Padua was a center for **humanism**, and Mantegna studied **Latin** there before leaving his teacher to work in Verona, **Rome**, and **Mantua** in the mid-1400s

In 1460, Mantegna began work for Lodovico III Gonzaga of Mantua, where he was appointed court artist. His best-known work there is his **fresco** series in the Camera degli Sposi in the Ducal Palace, executed in 1474. Here we see Mantegna's famous illusionism, where the ceiling is painted to resemble an ancient domed room with an open oculus, from where young girls and putti peer down into the room. Mantegna devised a perspective that takes into account the viewer's position below the fresco looking up at it, therefore, it is one of the earliest ceiling paintings done di sotto in sù, involving a dramatic foreshortening to stretch the space of the room upward. The walls were then covered with courtly scenes that show contemporary members of the Gonzaga family surrounded by courtiers, set in interior scenes and landscape views.

Leonardo certainly would have been invited to see this innovative use of spatial illusion while staying at the Ducal Palace in Mantua, as a guest of Isabella d'Este, the wife of Francesco II Gonzaga, in 1499. Leonardo had another opportunity to see the work of Mantegna in Rome, where, in 1488, Mantegna was invited by Pope Innocent VIII to fresco a chapel in the Vatican, a series of paintings that were destroyed in 1780. Soon thereafter, Mantegna returned to Mantua, where he remained the rest of his life. In 1497, he was commissioned by Isabella d'Este to paint a series of mythological scenes for her private study in the Ducal Palace, which Leonardo could also have seen. Leonardo, together with his friend, mathematician **Luca Pacioli**, had fled Milan in 1499, at the French advance into the city, and Mantua was a convenient stopping point on their way to Venice. They stayed there three months, where they would certainly have met the elderly Mantegna and cemented their shared interest in mathematical and pictorial perspective illusionism through a series of dinner conversations. *See also* CLASSICISM; MATHEMATICS.

MANTUA. In 1499, Leonardo fled **Milan** when the French Army, under King Louis XII, took control of the city, claiming hereditary rule through the first duke of Milan. Leonardo packed up his studio and left with his friend, mathematician **Luca Pacioli**, in December, three months after **Lodovico Sforza** had fled. Their first stop was Mantua, where they stayed in the Ducal Palace for three months as guests of Isabella d'Este. Mantua, located in the southeastern corner of Lombardy and surrounded by the Mincio River, was the seat of the thriving court of the Gonzaga family. The city was renovated under the Gonzaga, who came into power in the early 1300s, and by the late 1400s, it was known as one of the most important cultural centers in Italy.

The intellectual framework for the court was based on the humanist principles established by scholar Vittorino da Feltre (1378–1446). In 1490, Francesco II Gonzaga married Isabella d'Este, the daughter of the duke of Ferrara, and she became an important art patron, and an important female cultural and diplomatic leader in the **Renaissance**. In 1500, she traveled to Milan to persuade King Louis XII not to invade Mantua, and that same year,

she gave birth to her son, Federico II, who later became the first duke of Mantua.

While in Mantua, Leonardo would certainly have visited the church of Sant'Andrea, built by **Leon Battista Alberti** in the 1470s, in the classical style derived from **Marcus Pollio Vitruvius**. This church features one of the first barrel-vaulted interior naves of the Renaissance and exterior proportions that anticipated the interior. Alberti's rational architectural language must have influenced Leonardo's architectural plans found in his **notebooks**. Leonardo would also have seen the illusionistic wall and ceiling **frescoes** by **Andrea Mantegna** in the Ducal Palace, which reveal sharply foreshortened figures seen di sotto in sù, or as seen from below, and other illusionistic devices Leonardo certainly would have found related to his optical studies. *See also* CLASSICISM, HUMANISM; OPTICS; *PORTRAIT OF ISABELLA D'ESTE*.

MANUSCRIPTS A–M. *See PARIS MANUSCRIPTS.*

MAPS. *See* CARTOGRAPHY.

MARTINI, FRANCESCO DI GIORGIO (1439–1501). Francesco di Giorgio Martini was a Sienese artist and sculptor best known for his architectural treatise called the *Trattato di architettura, ingegneria e arte militare*, finished in the early 1480s. His treatise shows improvements to many different machines used for construction, for instance, the pile driver. Pile drivers had been used since antiquity to drive poles into the ground using human or animal labor, while Martini sought to improve upon the traditional wood-framed pile drivers used since antiquity by making a mechanical driver. Martini also designed the first centrifuga pump, used to lift mud, where the pump uses rotational energy to move the mud through the pump in an angular momentum. This manuscript was also based in part on **Leon Battista Alberti's** architectural treatise, which introduced classical architecture in the **Renaissance**, and **Antonio di Pietro Averlino Filarete's** designs for an **ideal city** called Sforzinda.

Martini's studies focused on military **architecture**, however, and he began his career by building fortifications for Duke Federico da Montefeltro of Urbino in the 1470s. Soon thereafter he began to design more elaborate fortifications, for example, an early star-shaped fortified castle that inspired his later ideal city plans. In the 1490s, Martini was hired to make a dome model for the **Milan Cathedral**, and he met Leonardo while working on the cathedral *tiburio*. Leonardo lived right across the square in a wing of the old Visconti palace and had also been hired as a consultant on the crossing construction. Martini was older than Leonardo, but they struck up a friendship, and in the summer of 1490, Leonardo and Martini went to Pavia together. Martini had been invited to Pavia to provide advice on renovating portions of the Pavia Cathedral, and he invited Leonardo to document their visit with sketches.

Martini was from Siena, and during his early career there he was responsible for maintaining the water supply and building the main fountain in the Piazza del Campo, and then he moved to Urbino to work as a military architect for Duke Federico da Montefeltro, where he had access to Montefeltro's vast library. Martini's *Treatise on Civil and Military Architecture* was enormously influential on Leonardo, who had become more involved in the study of both architecture and **geometry**, working with mathematician **Luca Pacioli**. Leonardo's ***Paris Manuscripts*** A and C appear to have been influenced in their organization by Martini's work, and indeed Leonardo owned one of Martini's manuscripts, now called the ***Codex Ashburnham 361***, located in the Biblioteca Laurenziana in **Florence**, which Leonardo annotated in the margins. He also copied part of Martini's *Treatise* on 12 folios of his Codex Madrid II. *See also* BRUNELLESCHI, FILIPPO

MARY MAGDALENE. A painting of Mary Magdalene located in a private collection in Switzerland (measuring 22.8 x 17.7 inches) has recently been attributed to Leonardo by art historian **Carlo Pedretti**. This painting, which depicts a partially nude woman with long brown hair and covered in a rich red robe set against a landscape background, is one of many **paintings** done of this subject that show

a repentant Magdalene with long curly hair flowing over her nude torso. This particular work was originally attributed to **Giampietrino**, a Milanese follower of Leonardo who is thought to have painted about eight other versions of the Magdalene, as well as nude figures of the mythological figures of Leda and Diana. This particular version shows a softly modeled figure with a sweet, youthful face and curly red hair. The background is similar to the atmospheric landscape of Leonardo's ***Mona Lisa***, which Leonardo's students would have been familiar with.

Pedretti has suggested that Leonardo painted this work together with his students in about 1515, just before leaving **Milan** for France. Pedretti first noticed the work while studying the work of Giampietrino, and he determined this particular version of the Magdalene is of exceptionally high quality. Most scholars do not agree with this attribution, and Carlo Bertelli has suggested that the painting could instead depict the *Death of Lucretia*, another new subject in **Renaissance** Italy. Although Pedretti suggested that technical analysis might confirm an attribution to Leonardo, no research has been able to clarify its attribution beyond a confirmation of its completion in the region of Milan in the first few decades of the 1500s. *See also* CATHOLICISM; LEONARDESCHI.

MASACCIO (1401–1428). Early Italian **Renaissance** painter Tommaso di Ser Giovanni di Simone, known as Masaccio, was a painter from **Florence** credited with advancing the realism in **fresco** painting. Although he died prematurely, in his short life his frescoes introduced **linear perspective** and **atmospheric perspective.** The two works Leonardo would have seen include his *Tribute Money*, from c. 1424, and his *Holy Trinity*, from c. 1428.

In 1424, Masaccio took over the completion of the Brancacci Chapel frescoes in Santa Maria del Carmine in Florence. The commission was originally given to his teacher, Masolino da Panicale, but when Panicale went to Hungary, Masaccio was left to paint the remaining scenes, which refer to the life of Saint Peter. The *Tribute Money* is the most famous scene because it shows an early, and perhaps the first, example of atmospheric perspective in the Renaissance. Here, the tax collector comes to speak with Christ, located in the center, and the apostles. Then we see Christ instructing Peter, appearing to the viewer's left, where he goes to retrieve coins from the mouth of a fish. Then, Peter appears a third time, now on the viewer's right, to hand money to the tax collector. Here, Masaccio has devised a sophisticated way of showing a compressed narrative with repeated figures and a story that is not chronological from left to right, but begins in the middle, conforming to pictorial visual hierarchy. The background is made from coal ash mixed with azurite blue to create a grey-blue color resembling the color shift that occurs when mountains are viewed from a great distance. In the foreground, the figures are modeled with an early example of **chiaroscuro**, highlighted by the shadows they also cast.

The *Holy Trinity* is a fresco commissioned in 1427, and located along the side wall of Santa Maria Novella in Florence. Here we see a triangular formation, with Christ on the Cross, God standing on a platform above Him, and an elder Virgin Mary and John the Evangelist flanking him to form a stable triangular composition. They stand in an illusionistic space that appears to recede back into a chapel above the painted sarcophagus and flanked by columns and covered with a coffered, barrel vault. Two steps lead up to the chapel, and kneeling on the outer edges of the lower step, enlarging the triangle, are the donors, perhaps members of either the Lenzi of Berti families. The orthogonal lines of the vault recede to the top step right above the sarcophagus, allowing scholars to calculate the exact measurements of the space. Then, the orthogonal lines of the figures recede to Christ in the middle, so there are two ways to measure, one architectural and one for the figures. This sophisticated system was perhaps designed with the help of **Filippo Brunelleschi**, a friend of Masaccio's. Here, the linear perspective is fused with religious meaning, where the repeated number three also refers to the Trinity. *See also* CATHOLICISM; MATHEMATICS.

MATHEMATICS. Leonardo's mathematical studies were primarily focused on **perspective** and **geometry**, the two mathematical skills most useful for painters in their visual approach to the world. Leonardo believed that the universe was organized in such a way that it could be understood by the human mind and explained mathematically, and throughout his life he sought to prove this fundamental notion by careful observations of nature. He also saw the world as formed from geometrical shapes constantly changing through physical forces, and he intuited that a study of their related patterns could tell us much about the parts of the world we cannot see. It was in **Milan** where he began studying the ideal measurements of the human body, as seen in his ***Vitruvian Man***, where he explored the movement of the body when superimposed on a circle and a square to form a triangle, the three basic geometric shapes Leonardo argued were the basis for all other shapes, with the circle being the perfect shape and the one most found in nature.

In the 1490s, he met **Fazio Cardano**, who taught mathematics at the University of Pavia, and during this time Leonardo wrote a short treatise on perspective and **optics**. Leonardo then studied geometry with **Luca Pacioli** in Milan and illustrated Pacioli's mathematical treatise, *De divina proportione*, published in 1509. His rhombicuboctahedron, an Archimedean solid polyhedron with 18 square and eight triangular faces on 24 identical vertices, is the most famous image by Leonardo, widely printed in subsequent editions of the treatise. Leonardo's superior drawing skills allowed him to present complex shapes with a high degree of visual accuracy through shading and shadowing. Later in life, he intended to write a treatise on the "geometry of motion," and while in **Rome** he designed a group of 176 topological transformations he called games, which appear in the ***Codex Atlanticus*** on a large folio entitled "De ludo geometrico." He hoped to use these patterns to analyze the movement of things in nature, for instance, water and air, but he was ultimately hampered by the limits of **Renaissance** mathematics.

Despite this, Leonardo also employed the geometry of angles to advance mapmaking in the Renaissance by taking into account perspective and optics, while surveying and measuring territories. By calculating the perspective angles of his maps and landscape views, he learned he could extrapolate aerial views, as seen in his *Imola Town Map*, with remarkable accuracy. For Leonardo, mathematics was the language of the universe, and he used it to describe many of the things he observed in nature, which he then sketched with remarkable visual accuracy. *See also* ARCHITECTURE; CARDANO, GIROLAMO; CARTOGRAPHY; *CODEX FORSTER*; ENGINEERING; LANDSCAPES, NOTEBOOKS, PIERO DELLA FRANCESCA; TOPOLOGY.

McCURDY, EDWARD ALEXANDER COLES (1871–19??). Leonardo scholar Edward McCurdy was educated at Oxford University and is one of the first scholars to translate Leonardo's notebook annotations and literary writings into English. He published one of the earliest monographs on Leonardo in 1904 (London, George Bell), and then a study of Leonardo's **notebooks** in 1906 (London, Duckworth), which was the first important study of Leonardo's work on paper and updated and republished in two volumes by Reynal and Hitchcock in New York 1939, and reprinted in 1945. He also published *The Mind of Leonardo da Vinci* in 1928 (London, Jonathan Cape), which is now widely available in a Dover edition (New York, Mineola, 2011). In this work, McCurdy explored Leonardo's thought process and interests set against his biographical background. He began with a narrative description of Leonardo's travels and then analyzed his notebooks, translating his mirror text into English, and finally, he talked about Leonardo's art. McCurdy was one of the earliest scholars to shift focus from Leonardo's **paintings** to include his complete oeuvre of scientific studies. *See also* BERENSON, BERNARD; BODE, WILHELM VON, FREY, KARL OTTO; LIPHART, KARL EDUARD VON; MORELLI, GIOVANNI; WAAGEN, GUSTAV FRIEDRICH.

MECHANICAL DRAGONFLY. *See* FLYING MACHINES, INVENTIONS.

MECHANICAL EAGLE. *See* FLYING MACHINES; INVENTIONS.

MECHANICAL ENGINEERING. *See* ENGINEERING.

MECHANICAL KNIGHT. *See* AUTOMATON; INVENTIONS.

MEDICI. Lorenzo de' Medici (1449–1492) was Leonardo's main patron during his early years in **Florence.** The Medici family had established their authority under Cosimo "the Elder" de' Medici (1389–1464), a wealthy banker who grew the family bank to become the largest in Europe during the late 1400s. Cosimo's grandson, Lorenzo (1449–1494), continued to rule Florence after the death of his father, Piero di Cosimo de' Medici, in 1469. His favorite artists included **Sandro Botticelli**, Leonardo's teacher, **Andrea del Verrocchio**, and the young **Michelangelo**. The Medici rose from a late medieval prosperous landowning family to establish themselves in the merchant class in Florence and eventually enter the nobility in 1532, by acquiring the hereditary title of the Dukes of Florence, which became the Grand Duchy in 1569, with the expansion of their territories around Tuscany.

The Medici originated in the Mugello hills around Florence, where in the Middle Ages they held land and established a thriving wool industry and worked in the textile guild, called the Arte della Lana, which was one of the seven major guilds that employed about one-third of the population of Florence. Through guild membership a family could become politically active in their community and help maintain fiscal records for the commune by overseeing the tax records of their industry. This guild became enormously influential, rivaling the Arte di Calimala, or textile guild, which imported raw cloth and dyed and finished it, and these guilds became major art patrons in the **Renaissance.** These newly expanded industries also began to codify their workshop practices and business policies to become powerful institutions that aided in the establishment of a new socioeconomic class, the merchant class, laying the foundation for not only the Medici family wealth of the Renaissance, but also the wealth of the commune during the 1400s

The Medici bank was first established in 1397, by Giovanni di Bicci de' Medici (c. 1360–1429), to facilitate their industry, but the family eventually became known primarily for their banking skills, where they introduced new accounting techniques, for example, the use of a book ledger and double-entry bookkeeping, as well as standardized units of measure to more accurately calculate profits and losses. They also initiated a fairer, more proportional tax system, which gained widespread support. Prior to this time, the main banking center was in Siena, but this shift in the late 1300s initiated eventual Florentine dominance in the region of Tuscany. This more sophisticated economy also came about with an increase in knowledge, including **mathematics** and other disciplines, which were revived from antiquity and expanded to meet modern needs. While rival families continued to contest Medici authority in Florence, the family managed to dominate Florentine politics and culture throughout Leonardo's lifetime under the rule of Cosimo, Piero, and Lorenzo. Upon Lorenzo's death in 1494, the family was sent into exile until 1512, and a republican government was established under **Piero Soderini**, who also commissioned Leonardo to work for the new government.

Leonardo met Lorenzo during his apprenticeship with Verrocchio, and after he became an independent artist in 1478, the **Anonimo Gaddiano** biographer noted that Leonardo was living in the Medici Palace by 1480, and working in a garden space in front of the monastery of San Marco near the Medici Palace. In 1482, Lorenzo commissioned Leonardo to create a silver lyre in the shape of a horse's head as a gift for Duke **Lodovico Sforza**, and he sent Leonardo to **Milan** to deliver the gift in person to help negotiate peace between the two rivals. Leonardo stayed in Milan for the next 17 years, where he completed his most famous works.

Although he spent most of his career in Milan, he returned frequently to Florence, where his father, stepmothers, and half brothers and sisters lived. In 1513, Leonardo moved to **Rome** at the invitation of Giuliano

de' Medici, the brother of the newly elected pope **Leo X**, who was Lorenzo de' Medici's second son, Giovanni di Lorenzo. There Leonardo lived near the Vatican and served as an architectural advisor to the pope. Leonardo's early participation in the **Platonic Academy**, sponsored by the Medici, which began as soon as he completed his apprenticeship with Verrocchio in Florence, connected him to the greatest scholars and artists of the Renaissance. Medici patronage was fundamental to Leonardo's career trajectory, and the Medici continued to support him throughout his life. *See also* ALBERTI, LEON BATTISTA; ARCHITECTURE; BRUNELLESCHI, FILIPPO; CLASSICISM, FICINO, MARSILIO; GHIBERTI, LORENZO; GHIRLANDAIO, DOMENICO, MIRANDOLA, GIOVANNI PICO DELLA, POLLAIUOLO, ANTONIO DEL, RAPHAEL.

MEDUSA SHIELD. Giorgio Vasari mentioned in his *Lives of the Artists* that a young Leonardo painted a head of Medusa on a wooden shield, a work that either does not exist or is now lost. Medusa was the Greek mythological Gorgon with hair made of serpents who turned warriors into stone if they looked into her eyes during battle, and her face became a traditional shield image in the **Renaissance**. If Leonardo painted such a shield, it would likely have been in either **Vinci** or **Florence** in the 1460s, and since shields were portable objects made for a domestic context, not as prized as panels, there is little chance that such a work survived.

Vasari's description is a detailed account of how Leonardo's father Piero asked Leonardo to paint the shield, which was carved by one of Piero's farm workers, as a favor for a friend. Leonardo created a composite image of a monster from a collection of bats and lizards he had dissected in his studio to create a painting of unprecedented imaginary realism, and when the work was finished, Piero decided to keep the shield, which he then sold to a Florentine merchant, who later on sold it to the duke of **Milan**. Like many of Vasari's tales, this story may be anecdotal, or it could be an embellished version of factual events; however, it is easy to imagine the young Leonardo studying animal **anatomy** in his studio and challenging his imagination to create new imagery. *See also* ANIMAL STUDIES; CLASSICISM; PAINTINGS.

MELZI, FRANCESCO (c. 1491–1568/1570). Francesco (de) Melzi was one of Leonardo's favorite students and lived with him at the **Clos Lucé** in France before inheriting Leonardo's studio upon his death in 1519. Leonardo stayed with the Melzi family when he arrived back in **Milan** in 1506, and there he met the 15-year-old Francesco and invited him to work as an apprentice in his studio. Melzi was from a minor noble family, and his father, Gerolamo Melzi, had worked as an engineer for the Sforza military, so the young Melzi grew up in the court and received an education in the courtly arts, where he was known for his beauty and elegance. Melzi is considered one of Leonardo's most talented students, and as Leonardo's heir, he was given the task of organizing Leonardo's **notebooks** for publication. Melzi was about 28 years old when Leonardo died, and he returned to his family villa at Vaprio, outside Milan, married, and had eight children, one of whom was Orazio. Orazio inherited Leonardo's notebooks upon his father's death in about 1570, and they remained untouched at the Melzi estate until his death, when the manuscript pages were separated into groups and sold off.

Melzi spent many years gathering together the pages of Leonardo's intended ***Treatise on Painting*** (*Trattato della Pittura*), which is now part of the *Codex Urbinas*, but nothing was ever published from the more than 5,000 pages. He hired two assistants to help him catalog Leonardo's pages and sought to organize the section on painting into chapters, but since the notes and images were not written in chronological or thematic order, Melzi was unable to create a coherent system. Nonetheless, his students made several copies of these pages, which were made available to **Giorgio Vasari** and other contemporary artists through the late 1500s.

Melzi continued his painting career back in Milan after Leonardo's death, and there he became a highly skilled painter, working in Leonardo's soft realistic style. Leonardo's ***Belle***

Ferronnière has been attributed to Melzi, while Melzi's *Columbina* was originally attributed to Leonardo. Melzi drew a rare sketch of Leonardo, seen in profile, as an older man with a long beard, which is considered the only accurate image of Leonardo (c. 1515, red chalk on paper, London, Royal Collection, RCIN 912726). This sketch could have been the one seen by Vasari at the Melzi villa in Lombardy, which Vasari copied in the frontispiece of his *Lives of the Artists*. Leonardo had a beard only late in life, which was unusual in Europe at this time. Yet, it is this enduring image that has shaped our view of the artist's appearance today. This drawing was part of Orazio Melzi's possessions sold to Italian artist Pompeo Leoni in about 1590. Leoni is responsible for dispersing the collection through sales he made throughout Europe, some of which he took with him to Spain, where he introduced Leonardo's ideas to the royal court in Madrid. *See also* FRANCIS I; LEONARDESCHI; ROME; SALAÌ; SFORZA, LODOVICO.

Francesco Melzi, *Portrait of Leonardo da Vinci*, after 1510, red chalk on paper, 10 8 x 7.5 inches, London, Royal Library, Windsor Castle.

METALLURGY. *See* CANNONS CHEMISTRY; SCULPTURE; VERROCCHIO, ANDREA DEL.

MICHELANGELO BUONARROTI (1475–1564). Italian **Renaissance** painter, sculptor, and architect Michelangelo was born outside **Florence** 23 years after Leonardo. In 1488, Michelangelo entered the shop of **Domenico Ghirlandaio** as an apprentice, and the next year he began to work for the **Medici** and attended the **Platonic Academy**. There he met humanist scholars **Marsilio Ficino** and **Giovanni Pico della Mirandola**, among others. He then spent a few years in Bologna and **Rome** during the Medici family exile from Florence, before returning to the city in 1499, receiving a commission to carve a figure of David to be placed in a niche on the exterior of the Florence Cathedral. When the **sculpture** was finished in 1504, a group of advisors, featuring the elder Leonardo, decided the colossal figure should instead be placed in front of the government palace in Florence, called the Palazzo Vecchio. This colossal figure is credited with introducing the classical style to Florence through the heroic nude figure carved in marble. Today, a replica of the *David* stands next to the palace entrance, while the original sculpture is in the Accademia Museum in Florence.

Leonardo had just returned to Florence in 1503, and in 1504, he was commissioned by **Piero Soderini**, the gonfalonier of Florence, to paint a scene of the ***Battle of Anghiari*** on the walls of the council chamber, called the Sala dei Cinquecento in the Palazzo Vecchio, while Michelangelo was commissioned to paint the *Battle of Cascina* on the opposite wall. Both battle scenes depicted historic Florentine victories against the Milanese at Anghiari in 1440, and against Pisan troops at Cascina in 1364. Both works remained unfinished, and beginning in 1555, the room was enlarged and renovated under **Giorgio Vasari** for Duke Cosimo I de' Medici, at which point the unfinished **paintings** were lost and Vasari painted a new series of battle scenes on the extended walls. The lost paintings are known today through copies made of the cartoons prior to their destruction, and both reveal an interest in representing figures in motion. While Leonardo was interested

in the grimacing faces of men in battle and their relation to their horses rearing up around them, Michelangelo was interested in representing complex movement in the human figure and the display of muscles in tension.

Leonardo's cartoon is represented in a 1603 copy by Flemish Baroque painter Peter Paul Rubens (1577–1640), now in the Louvre Museum in Paris, based on an earlier engraving of Leonardo's cartoon, while a copy of Michelangelo's cartoon was made by his student, Bastiano da Sangallo (1481–1551), now in Holkham Hall, Norfolk. Vasari wrote in his *Lives of the Artists* that Michelangelo and Leonardo were rivals, and he described this commission as a contest. These rivals disliked one another, according to Vasari, and scholars have since then wondered if that is an accurate assessment or an embellished tale of competition. Leonardo abandoned his work after he finished his sketches, devised a new scaffolding system, and began to paint on the walls, while Michelangelo left his work after he completed a series of **drawings** and a full-scale cartoon to return to **Rome** at the request of Pope Julius II to work on his funerary monument. *See also* CLASSICISM; HUMANISM, MUSEUMS, RAPHAEL.

MILAN. Leonardo lived in Milan during two periods, from 1482–1499, called his First Milanese Period, and 1506–1513, during his Second Milanese Period. The Duchy of Milan, part of the Holy Roman Empire, was created in 1395, for Gian Galeazzo Visconti, who bought the noble title. The Cathedral of Milan was begun by the Visconti, who also built a family castle and city walls. The Sforza family then came into power in 1450, upon the death of the last Visconti male heir, Duke Filippo Maria, in 1447, and a brief attempt at communal rule that was contested by numerous hereditary claims. Unable to negotiate a new type of shared government, noble mercenary soldier Francesco Sforza (1401–1466), who had previously worked for the Visconti, conquered Milan and established the Sforza dynasty. During his rule, he founded the Ospedale Maggiore, one of the oldest hospitals in Italy, restored buildings and walls, and brought more water into the city with the construction of a channel linked to the Adda River.

Francesco established a court in Milan, overseen by humanist scholar **Francesco Filelfo**, who was thought to be a distant relative of Leonardo. Filelfo had spent most of his career in Milan, but he returned to his native **Florence** in 1481, at the invitation of Lorenzo de' **Medici**, only to die there several weeks later. It remains unclear how well Leonardo might have known Filelfo, but he certainly moved in the same social circles. Francesco's son, Galeazzo Maria Sforza (1444–1476), then ruled Milan for 10 years before being assassinated, and he was succeeded by his young son, Gian Galeazzo Sforza (1469–1494), whose uncle, **Lodovico Sforza**, acted as his regent. When Gian Galeazzo died in 1494, Lodovico took over the Duchy. It was during the last two decades of the 1400s that Milan flourished under Lodovico, who invited artists and scholars from throughout Italy and Northern Europe to work at his court.

Leonardo arrived in Milan in 1483, at the invitation of Lodovico when he ruled as regent. **Giorgio Vasari** claimed Leonardo first came to Milan to participate in a **music** contest, after having made a silver lyre in the shape of a horse's head, and Lodovico hired him as his architectural engineer and Leonardo moved into a wing of the old Visconti Palace, called the Corte Vecchia, across the square from the **Milan Cathedral**. During this time, the cathedral was nearing completion, but it lacked its crossing dome. Several architects were consulted, including **Donato Bramante**, **Francesco di Giorgio Martini**, and Leonardo. Leonardo made a few **drawings** but never worked on its construction. While in Milan, Leonardo painted the ***Last Supper*** and the ***Lady with an Ermine***, and he primarily worked on his **notebooks**, mainly the ***Codex Atlanticus*** and the ***Codex Trivulzianus***. He also painted a now-lost **fresco** in the **Sala delle Asse** in the Castello Sforzesco. In addition, he worked on several urban plans for an **ideal city**, which included a new water system based on his extensively observations of water movement.

In 1499, French soldiers entered Milan and destroyed an equestrian monument in

Leonardo's studio that he had been working on for Lodovico Sforza. It was likely for this commission that Leonardo was given the courtyard of the old Visconti Palace as his workshop, where he had enough room to store the colossal horse. The large palace had a wing still inhabited on a part-time basis by Duke Gian Galeazzo Sforza as a teenager, while Leonardo stayed in another wing with a large audience hall that overlooked the courtyard. This large room was also likely where Leonardo devised the ornithopter, or **flying machine**, which was set up on the roof of the palace. Soon after the French invasion, Leonardo left Milan with his friend, mathematician **Luca Pacioli**, and several of his assistants.

Leonardo returned to Milan in 1506, where he established a painting studio and trained many Milanese students in his now-famous **sfumato** style, including **Bernardino Luini** and **Marco d'Oggiono**. He likely returned to design a bronze equestrian monument for **Charles II d'Amboise**, the French governor of Milan, but the project never materialized and Leonardo returned to Florence the following year for family matters. When he returned to Milan in 1508, he moved into a house near the large Romanesque Church of Santa Babila, near the west side city walls, where he continued his unfinished painting projects and worked on his notebooks until he moved to **Rome** in 1513. *See also* FILARETE, ANTONIO DI PIETRO AVERLINO; INVENTIONS, SCULPTURE.

MILAN CATHEDRAL. The Cathedral of **Milan** is one of the largest churches in Italy and the only Gothic church done in the French Gothic style and overseen by French and German architects. Construction began in 1386, under the rule of Gian Galeazzo Visconti (1351–1402), the first duke of Milan, and his cousin, Archbishop Antonio da Saluzzo. Construction initially progressed rapidly, and the cathedral was half completed by the death of Gian Galeazzo in 1402, while the nave to the sixth bay was completed during the rule of Duke Francesco Sforza (1401–1466), at which point construction stalled until the 1480s. In 1487, **Donato Bramante**, Leonardo, **Francesco di Giorgio Martini**, and three other architects entered a competition sponsored by **Lodovico Sforza** for the *tiburio*, or crossing tower.

Leonardo's design, found in the ***Codex Atlanticus***, fols. 850r–851r, includes a dome with double vaults and an octagonal tower plan, while fol. 719r shows a variety of drawings for the centering needed for the dome and lantern construction, and fols. 535r and 537r have sketches of the scaffolding needed for construction. Although Leonardo's plans never materialized, in the summer of 1490, Lodovico Sforza had Leonardo and Francesco di Giorgio Martini travel to Pavia to see how the Pavia Cathedral construction was progressing, and the two architects developed a lasting friendship. Martini returned to Milan after two weeks in Pavia, but Leonardo, deeply impressed with the library, stayed six months to study **perspective** and the optical works of Alhazen. There he met **Fazio Cardano**, a mathematics professor at the University of Pavia, and began to develop his studies of **geometry**. *See also* ALBERTI, LEON BATTISTA; ARCHITECTURE; BRUNELLESCHI, FILIPPO; *CODEX TRIVULZIANUS*; ENGINEERING; MATHEMATICS; OPTICS.

MILITARY ENGINEERING. *See* ENGINEERING; INVENTIONS; *PARIS MANUSCRIPTS*.

MIRANDOLA, GIOVANNI PICO DELLA (1463–1494). Giovanni Pico della Mirandola, known as Pico, is best known for his discourse the *Oration on the Dignity of Man*, written in **Florence** in 1486, when he was 23 years old, after completing seven years of university study in a variety of subjects in Bologna, Ferrara, Padua, Paris, and Florence. Arriving in Florence in 1484, he met Lorenzo de' **Medici**, who became his lifelong patron, as well as **Marsilio Ficino**, his eventual teacher in Florence, and his friend, contemporary humanist **Angelo Poliziano**. Pico's *Oration* was an introduction to what he hoped would be a large treatise summarizing the great human achievements through history, but the treatise was never completed due to his premature death at age 31. In his *Oration*, which was based on Platonism, he argued that through education, a philosopher can ascend to the

level of angels, and that attaining knowledge was a human's greatest, most noble goal. Unlike animals, which are bound to instinctual behavior patterns, humans have the ability to craft rational decisions through their free will, making them superior to any other creature on earth. He noted that transformation was ever-present in all institutions on earth and in nature, so a human's desire to better him/herself was part of the natural process. Human progress, according to Pico, is a reflection of God's greatness.

Pico was also interested in joining Eastern Judaic mysticism with his Western, Christian beliefs, which he considered compatible. He had studied Hebrew and Arabic in Padua, and noted that some Christian mystics sought a more rigorous mystical interpretation of Christianity through a study of the Hebrew Kabbalah, which was used as an aid in their interpretation of the Bible. Pico was introduced to a number of these mystical manuscripts while in Perugia recovering from a wound inflicted by the husband of his lover, a cousin of Lorenzo de' **Medici** who lived in Arezzo. In the late 1400s, Perugia maintained an important university and library, and during his brief time there Pico was introduced to Chaldean philosophy, as well as the Hebrew Kabbalah and the Hermetic writers, all of which he described with enthusiasm in letters to Ficino. From these studies, Pico established a Christian Kabbalah tradition by integrating this esotericism with the ideas of Plato. Pico considered these ancient sources to express the same ideas about God, just in a different language; however, because of his interest in this so-called "magic," he was condemned by the Papacy for heresy and his *Oration* became the first book in history to be banned by the Church.

After fleeing to France, Pico was allowed to return to Florence with the help of the Medici, who provided him with a villa in Fiesole. He eventually became a follower of **Girolamo Savonarola**, a Dominican friar who promoted a more puritanical interpretation of Christianity through the suppression of secular culture and the renewal of the Church. Both Pico and Poliziano died suddenly in 1494, in mysterious circumstances, perhaps of arsenic poisoning. Leonardo's early interests in a broad education were consistent with Pico's educational background, except that Leonardo never received a formal education and only wrote a limited amount of self-taught **Latin**. Thus, Leonardo was never technically considered a humanist, but his own ideas were profoundly shaped by the humanist ideas that flowed throughout Florentine culture in the 1400s. Although many scholars have sought to align Leonardo's interest in numbers with such mystical numerology as that promoted by Pico, Leonardo instead focused his interest on numbers with mathematical disciplines like **geometry**. *See also* CATHOLICISM; CLASSICISM, HUMANISM; MATHEMATICS; PLATONIC ACADEMY.

MIRROR WRITING. *See* LEFT-HANDED.

MITER LOCK. *See* CANAL LOCK.

MONA LISA. This half-length portrait (30 x 21 inches, **oil** on white poplar wood, Paris, Louvre Museum) is called either the *Mona Lisa* or *La Gioconda*, and is likely a portrait of Lisa Gherardini, (1479–1542), the wife of Francesco del Giocondo, a wealthy cloth merchant from **Florence** who commissioned the painting. The painting's name was first described in **Giorgio Vasari's** biography of Leonardo from 1550, and a note written by Florentine official Agostino Vespucci in 1503 mentions the commission. Lisa was 15 at her marriage in 1495, while her husband was two decades older and had been married twice before to women who died in childbirth, as was common in **Renaissance** Italy. They had five children together, and Lisa outlived her husband to spend her remaining years in the Convent of Sant'Orsola, where her sister was a nun. This portrait, perhaps commissioned by her husband in 1503, was likely meant to decorate their new house on Via della Stufa, which was purchased that same year. The painting remained unfinished upon Leonardo's death in France, however, where it entered the collection of King **Francis I** and eventually formed part of the original collection of the Louvre Museum in 1797. Its early exposure in a public museum setting helped to spread its fame.

The portrait is, in many ways, consistent with others of the era, while it also shows Lisa gazing directly out at the viewer to provide a sense of familiarity and realism previously limited to male portraiture. It is her gaze, together with the subtle smile, that makes the *Mona Lisa* unique. Here we see a half-length figure, seated against a portico wall that opens to show an imaginary landscape. The bases of two columns are cropped out of the painting on either side of the wall. Lisa is seated slightly angled to the viewer's left, which breaks the frontal pose to provide greater depth. Her hands, softly modeled in a golden **sfumato**, rest in an elegant pose on the arm of a wooden chair. She wears a **monochromatic** dress with dark yellow sleeves beneath a dark robe trimmed in gold. A transparent veil covers her head and hangs down one shoulder. Lisa wears no jewelry—no necklace, no elaborate headpieces, and no rings, which is also unusual for the era. Her reddish-brown hair is parted in the middle and smoothed out beneath the veil, and falls in ringlets around her face to gather at her shoulders. Her face, which is what first attracts the viewer's eyes, is also softly modeled in a warm, golden tone with subtle color gradations to show volume. She turns her head slightly toward the viewer and looks directly out of the painting with both of her eyes trained off to the left and out of the painting. She offers a smile of familiarity to the viewer, so we must know her. The background is a hazy landscape view of winding roads done in earth tones that lead the eye back to a land surrounded by jagged mountains fading into a slate blue atmosphere. This is called **atmospheric perspective**.

Although Lisa's smile can be, and has been, interpreted in many ways, its enigma is most likely the result of Leonardo's desire to heighten the realistic style he had been perfecting to give her a sense of life, humanity. The careful pose and subtle expression would have shown her to be a *gentildonna*, or a woman of noble class who is educated and models "correct" behavior. This noble behavior is what set the aristocracy apart from the masses, and both Lisa and her husband belonged to the *popolo grasso*, or wealthy nonnoble class, who sought to emulate noble behavior. This behavior is described in such writings as **Baldassare Castiglione**'s *The Book of the Courtier*, written in 1507, and based on his observations of courtly culture in both **Mantua** and Urbino at the turn of the century. Although the majority of the book is dedicated to male behavior models, Castiglione also described the ideal woman as educated, graceful, modest, prudent, charming, and with a similar sense of sprezzatura, or effortless nonchalance. Clearly, Leonardo was working to visualize this description in his portrait of Lisa, a work commissioned to signify the family's social aspirations.

The *Mona Lisa* is also unique in its depiction of a female sitter gazing directly out of the painting, which, although common in male portraiture, was considered a bold gesture for women, who were encouraged to cast their eyes downward in humility and not encourage the attention of men. The highly realistic style and use of a columned loggia with a detailed landscape background is found in earlier Renaissance portraiture, those females seen in either profile or a three-quarter view with their eyes cast downward. In Leonardo's work, Lisa's eyes are just slightly above the horizon line, which he carefully measured to reveal a mathematical exactitude.

Leonardo spent almost two decades in **Milan**, but in 1503, he returned to Florence and joined the Guild of St. Luke. He likely received this portrait commission soon after his arrival, but once he began working on a mural of the ***Battle of Anghiari*** for the government of Florence, he was unable to complete the work and eventually abandoned the mural, taking the painting with him back to Milan in 1506, where he continued to work on it in a style consistent with his later years from after 1513. Certainly, Leonardo would have sketched out the work in Florence, however, since a pen-and-ink drawing attributed to **Raphael** from 1504 (Paris, Louvre Museum) appears to be based on the Mona Lisa. This sketch shows a woman with the same face, as well as similar clothing and pose, set against a portico flanked by columns. This sketch is perhaps the source for Raphael's *Young Woman with a Unicorn*, c. 1506 (**Rome**, Galleria Borghese), which shows a young woman gazing directly out of

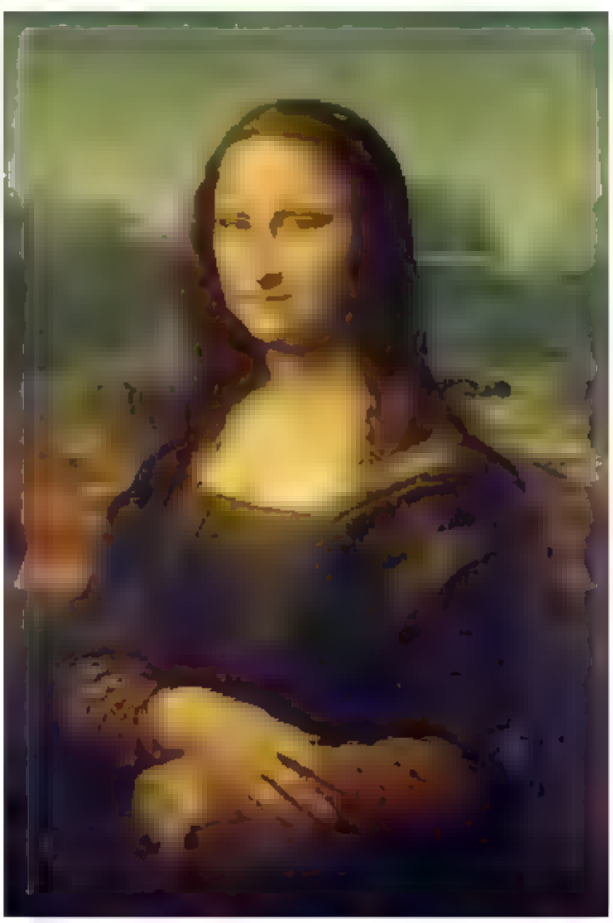
the painting with the same gesture as *Mona Lisa*. Raphael is documented as having visited Leonardo's studio in Florence, where he would likely have seen the *Mona Lisa*, and this formula eventually became the standard for High Renaissance female portraiture.

Later copies of the *Mona Lisa* are located in the Walters Art Museum in Baltimore, the National Museum of Art in Oslo, the Hermitage in St. Petersburg, and a particularly high-quality example in the Prado Museum and attributed to either of Leonardo's students, **Salai** or **Francesco Melzi**. A famous copy is the ***Isleworth Mona Lisa***, which at times has been attributed to Leonardo. Some of these versions show full flanking columns, which some scholars have suggested were based on another version of the *Mona Lisa* rather than the Louvre *Mona Lisa*, which was cut down at some point, but that hypothesis has been proven wrong because the dating does not match up.

Upon Leonardo's death, his student Salai perhaps inherited the painting, along with Leonardo's personal possessions, while Francesco Melzi inherited Leonardo's **notebooks**, and Salai sold the painting, along with two others, to Francis I for the royal collection. Some scholars think Leonardo made two versions of the *Mona Lisa*, especially given that a 1517 document mentions the portrait was commissioned by Giuliano de' **Medici**; therefore, the first version, with columns, could have been commissioned by Francesco del Giocondo in about 1503, and remained unfinished, in the possession of Salai, upon Leonardo's death, while a later version could have been commissioned by Giuliano de' Medici in 1513, the year his brother was elected Pope **Leo X**, which was the same year Leonardo arrived in Rome. This one, some scholars argue, was the version sold to Francis I in 1518, and is now in the Louvre.

High-resolution scans of the painting have shown that parts of the painting were reworked, and Lisa might originally have worn a headpiece like those fashionable in Milan at the time. Despite some overcleaning, which might have erased her eyebrows and eyelashes, the painting is in excellent condition. The original frame was removed at some point, and the painting is braced on the back to prevent further cracking and has a modern flexible oak frame in the Renaissance style.

The provenance history of the Louvre *Mona Lisa* continued long after Leonardo's death. It was first located in the Palace of Fontainebleau, where the king maintained his painting collection, then it was transferred to Versailles Palace when King Louis XIV moved the royal court there, and then Napoleon exhibited it in his bedroom before moving it to the Louvre as part of the original museum collection. The painting was removed from the museum to protect it during wartime, but in 1911, it was stolen by a member of the museum staff, who had carried the painting out under his coat and attempted to sell it to the Uffizi Gallery in Florence. After two separate incidents of vandalism, the painting was placed behind thick glass, where it was protected from several



Leonardo da Vinci, *Mona Lisa*, 1503–16, 30 x 21 inches, oil on poplar wood, Paris, Louvre Museum.

more attempts at vandalism. The work has traveled for several exhibitions in the United States, Japan, and Russia, but it has remained in the Louvre since 1974. The *Mona Lisa* continues to fascinate people, and it has been the source of many stories, theories, works of art and caricatures, and the subject of thousands of studies and several novels. *See also* *BELLA PRINCIPESSA*, *BELLE FERRONNIERE*; *GINEVRA DE' BENCI*; *LADY WITH AN ERMINE*; LANDSCAPES, MUSEUMS; *PORTRAIT OF ISABELLA D'ESTE*, PORTRAITS.

MONOCHROMATIC. The word *monochromatic* refers to the ancient Greek word for one **color**. Monochromatic colors derive from a single hue that is made lighter or darker with the addition of white or black. Prior to Leonardo's era, artists showed depth in a painting by contrasting with different colors, for example, **Michelangelo**, or seeking color harmonies, like **Raphael**. Leonardo sought a solidity of form and a more realistic three-dimensionality through a fuller tonal range of a single color, which allowed for a more effective use of **light** and dark contrasts, called **chiaroscuro**. Chiaroscuro provides a more cohesive sense of volume and visual unity, while Leonardo's restricted palette of earth tones allowed the viewer to explore the shape and volume of the objects depicted in their surrounding space. He built up color with **oil** glazes set on a neutral background and favored a subtle yellow to provide a soft lighting and **sfumato**, or haziness. This new technique was made possible with oil pigments that can be layered, unlike the more traditional **tempera** paint.

Leonardo's ***Mona Lisa*** is the most famous example of his characteristic monochromatic color palette. Here, the young woman is shown in a dark brown gown softened and warmed by a surrounding yellow tone, and shaded dark and light to show the absence of light in the folds of the drapery, together with the presence of light upon the arms and the shoulder closest to the viewer. The earth tones include an earthy red mid-ground and slate blue background. Leonardo did not use colors bright enough to distract the eye in their surface appeal, but instead his color palette required a more scientific analytical observation of form and shape. *See also* ATMOSPHERIC PERSPECTIVE; CLASSICISM; OPTICS.

MORELLI, GIOVANNI (1816–1891). Italian art connoisseur Giovanni Morelli established a scientific method of examining the minor details in a work of art he argued best revealed the identity of the artist. Morelli studied medicine in Germany, and upon his return to Italy, he used his studies of human behavior and **anatomy** in the examination and attribution of works of art, which he published in a series of articles collected together in *Die Werke Italienischer Meister* in 1880, using a pseudonym. His new technique involved the careful observation of the "subconscious" areas of a work of art—the details traditionally overlooked by connoisseurs—and it was widely adopted by early art historians and dealers the likes of **Bernard Berenson** and **Jean Paul Richter**. He focused his formal analysis on the hands, ears, and other secondary or incidental aspects of a sitter, which he argued best revealed the artist's identity.

It was Morelli's scientific method, used in the initial attributions of Leonardo's work, that clarified his artistic formation in the workshop of **Andrea del Verrocchio**. Despite his success, Morelli clashed with German art connoisseur **Wilhelm von Bode** and attacked his attribution work, arguing, for example, that the ***Ginevra de' Benci*** portrait was by Verrocchio rather than Leonardo, and Morelli also suggested that some of von Bode's Leonardo attributions were actually Flemish followers. Meanwhile, Morelli's student, Richter, was working on an anthology of Leonardo's writings during this time period, and together they tried to sort out Leonardo's early career. Richter introduced Morelli to Berenson, who used Morelli's unique method of connoisseurship to establish himself as an international specialist in Italian **Renaissance** painting. *See also* LIPHART, KARL EDUARD VON; WAAGEN, GUSTAV FRIEDRICH.

MUSEUMS. Leonardo's art-historical fame was first built on his small collection of **paintings**. His early work, done in **Florence**, includes his ***Annunciation***, now in the Uffizi Gallery in

Florence, which also houses **Andrea del Verrocchio's** *Baptism of Christ* and Leonardo's unfinished ***Adoration of the Magi***. A collection of Madonna and Child paintings, some of which are not universally attributed to Leonardo, can be found in more diverse locations, for instance, the Hermitage Museum in Saint Petersburg, the Alte Pinakothek in Munich, the Scottish National Gallery in Edinburgh, and the National Gallery of Art in Washington, D.C. Leonardo's Milanese work includes two wall murals that remain in situ in the Convent of Santa Maria delle Grazie and the Castello Sforzesco in **Milan**, but it seems that when he left Milan in 1513, he took his panel paintings with him to **Rome**, where he perhaps left his ***Saint Jerome in the Wilderness***, which is now located in the Vatican Museum, although it remains unclear how it entered the collection.

When Leonardo moved to France in 1516, at the invitation of King **Francis I**, he took his entire studio to **Clos Lucé**, which is now a public museum. His studio was disassembled after his death, and his most famous paintings entered the royal collection and then the Louvre Museum in Paris. These include his ***Virgin of the Rocks***; ***Belle ferronnière***, which retains its French name; ***Saint John the Baptist***; and the ***Mona Lisa***.

Since then, Leonardo's **notebooks**, which were disassembled and widely dispersed after his death, have been organized and reassembled into codices and drawing collections now located in the Biblioteca Ambrosiana and the Sforza Castle in Milan, the Victoria and Albert Museum, the Royal Library at Windsor, the Institute de France in Paris, and the National Library in Madrid, among other places. These **drawings**, which have historically been less accessible to museum visitors than Leonardo's paintings, are currently being digitized and made available in facsimile editions.

Finally, Leonardo's **inventions** have recently received more attention as scientists and historians have attempted to recreate many of the artist's concepts into working models. The Leonardo da Vinci Museum in Florence is dedicated to showcasing Leonardo's scientific achievements in the areas of mechanics and earth, water, air, and fire, while this hands-on, educational museum hosts traveling exhibits throughout Europe and the United States. The Leonardo da Vinci Museum of Science and Technology in Milan includes working models of Leonardo's **submarine**, mechanical eagle (***Paris Manuscript*** B, fols. 73v, 74 v, and r, 75r), and **crossbow**, among other things. Today, Leonardo's name is often evoked for a broad range of science museums, notably interactive children's museums. Several large exhibitions are being planned for 2019, at the 500th anniversary of Leonardo's death, including blockbuster shows at the Uffizi Gallery in Florence and the Louvre Museum in Paris, as well as at the Leonardo Museum in Leonardo's birth town of **Vinci**, which holds one of the most extensive collections of Leonardo's models, hosts academic conferences, and maintains a digital archive of Leonardo's writings. *See also* AUTOMATON; ENGINEERING.

MUSIC. Like many artists and scholars of the **Renaissance**, Leonardo had some training in music, which was considered integral to a humanist education. Musicians were employed in aristocratic courts and patronized by the emerging merchant class, and the advent of the printing press in the mid-1400s allowed for an increase in printed music, making written scores more accessible to a broader class of people. The musical language grew to include a wider range of rhythms, forms, and notations, and new musical instruments were introduced, while medieval stringed instruments were modified to allow for this greater variety of musical expression.

Little is known of Leonardo's musical background, but the **Anonimo Gaddiano** mentioned that Leonardo taught music to Atalante Migliorotti, (1466–1532), who accompanied Leonardo to **Milan**, where he became a skilled luthier and musician patronized by Isabella d'Este of **Mantua**. Leonardo's drawing of a nude young man playing a stringed instrument could be a portrait of Atalante. **Giorgio Vasari** noted in his *Vite* that Leonardo played the lira da braccio, and made sketches of both a *lira da braccio* and the newer *lira da gamba*, the prototype of the cello. Vasari mentioned that Leonardo created a *lira* in the shape of a horse's head with

silver parts, commissioned by Lorenzo de' **Medici** as a peace offering to his rival, Duke **Lodovico Sforza**. Leonardo brought the lyre to Milan and stayed there in the patronage of the Sforza for the next two decades. No **drawings** of this lyre exist in Leonardo's **notebooks**, but a skull-shaped lyre recently reconstructed in Cremona perhaps recalls Leonardo s Milanese instrument, or the lyre could be modeled on an ancient lyre made of wood covered in silver, or with a silver horse's head on the arms or sound box of the lyre, much like those from ancient Mesopotamia that are carved and decorated in metals and precious stones.

The *lira da braccio*, or arm-held lyre, was a bowed instrument more similar to a medieval viola and was used in courtly culture to accompany poetry and storytelling. These instruments were popular in Northern Italy and anticipated the famous violins made in Brescia and Cremona during the next several centuries. They also appear in the **paintings** of **Raphael** and Venetian painter **Giovanni Bellini**, among others, who showed them being played by music-making angels. Leonardo also made sketches of other stringed instruments, for instance, a stringed organ called a *viola organista* (***Paris Manuscript*** H, fol. 45v), which resembles a hurdy-gurdy and anticipates the harpsichord, and he wrote descriptions of sound experiments made with stringed instruments in his ***Codex Atlanticus***. The *viola organista* appears in several rough sketches, where Leonardo seemed to be working out a variation on an existing instrument by working through ideas for a new methods of volume control with a mechanical belt that acts as a bow

Leonardo was described by a number of biographers as a musician, and the *lira* played by the angel in **Giovanni Ambrogio de Predis's** side panel, made for Leonardo's ***Virgin of the Rocks*** (London, National Gallery), likely depicts the instrument Leonardo played. Musical proficiency was increasingly viewed as important to the arts and literature, and became an important part of a humanist education, as evidenced by Florentine scholar **Marsilio Ficino**, an accomplished musician who composed classical hymns and performed at the Medici-sponsored **Platonic Academy** in **Florence**, with which Leonardo was associated in the 1480s. Leonardo owned a copy of Ficino's commentaries on Plato, where Ficino spoke about the music of the spheres, an ancient philosophy based on the notion that the movement of the sun, moon, and planets creates harmony as a kind of orbital resonance. Pythagoras had discovered that pitch notes reveal consistent numerical ratios, as best seen on stringed instruments, so the link to **mathematics** was already made in the earliest studies of music.

Leonardo could also have known Franchino Gaffurio, head of the choir at **Milan Cathedral**, who wrote a treatise called *De harmonia*, which expanded on the musical work of Boethius (c. 480–524), whose *De institutione musica* was influential in medieval music. Leonardo might have formulated his sketched connections between the human trachea and the mechanisms of a wind instrument based on his study of Gaffurio's choir music, and his interest in acoustics, which for him was an examination of the mechanics of sound, permeates his notebooks. Most of Leonardo's musical observations took place in Milan, and he made about 40 sketches of bells to show how pitch can be derived. In a drawing of a bell in the second book of the ***Madrid Codices***, fol. 75, Leonardo shows us an experiment whereby he sought to change the pitch by striking the bell on different parts of its surface.

In the ***Codex Arundel***, fol. 175r, we find a design for a giant trumpet that has been recreated by the Leonardo Museum in Milan, which travels widely and has an important online presence. He also designed a musical cannon (a play on the term *musical canon*), a type of a giant music box, sketched in his *Codex Arundel*, fol. 136r, where a wheel with four teeth would turn with a crank to strike thin metal plates designed inside pipes similar to those of an organ, thereby creating four sounds that would follow one another, like a musical canon. He also designed a stretch drum, seen in the *Codex Arundel*, fol. 175r.

Leonardo's acoustical studies were similar to his optical studies. For example, he seemed to understand that, similar to the mathematical calculation of how objects diminish in size when distance increases, sound also decreases with

distance, while sound decay is similar to the decrease in visual clarity of an object when seen from a distance. Musical notations and descriptions also appear throughout Leonardo's notebooks, and in some cases, they appear together with romantic phrases similar to the love-poems of Francesco Petrarca (1304–1374) and **Angelo Poliziano.** For Leonardo, music was similar to painting in its ability to generate both artistic and scientific inquiry. *See also* ALBERTI, LEON BATTISTA; BELLINCIONI, BERNARDO; CASTIGLIONE, BALDASSARE; CELLINI, BENVENUTO; CLASSICISM; ENGINEERING; GALILEI, GALILEO; HUMANISM; INVENTIONS; *LADY WITH AN ERMINE*; LEFT-HANDED; LOMAZZO, GIOVANNI PAOLO; *PORTRAIT OF A MUSICIAN*; 33-BARREL ORGAN; *TREATISE ON PAINTING*.

N

NOTEBOOKS. Leonardo made more than 6,000 sheets of annotated **drawings** and writings explaining his careful observations of the physical world, ideas about art, and technical and scientific pursuits. He planned to publish these notebooks in a series of treatises on painting, **anatomy**, and other subjects, but after his death the books were disassembled and more than half of them lost, while others were gathered together in public and private collections. The existing notebooks have gradually been published, beginning in 1651, with an extract from the *Codex Urbinas* called the ***Treatise on Painting***, while there remains the possibility that more notebooks and individual sheets will resurface. In these books, in which Leonardo likely wrote on a daily basis, he posed questions and made observations about the world around him. His writing, a mirror writing, was due to the fact he was **left-handed** and never trained to write with his right hand.

It is generally thought that Leonardo began his notebooks in about 1485, in **Milan**, where he brought together his art studies in **Florence** with his scientific pursuits to establish his own beliefs about the world. These sketches were primarily architectural and **engineering** drawings made during the time Leonardo worked for **Lodovico Sforza** as an advisor on the crossing of the **Milan Cathedral** and various Sforza fortifications. Like Aristotle, Leonardo sought to understand the world through his own firsthand examination of nature rather than through the reading of academic studies. Anatomy, **physiology**, proportion, and **geometry** were areas that interested Leonardo throughout his life, and when he met mathematician **Luca Pacioli** in Milan in 1496, he began to postulate a mathematical premise for the underlying order of the universe, which appears in the ***Codex Atlanticus***. In 1498, Leonardo provided illustrations for Pacioli's *De Divina Proportione*, and during that same time he wrote a lengthy *paragone* on the superiority of painting over **sculpture**.

When Leonardo fled Milan with Pacioli in 1499, they went first to **Mantua** and then to **Venice**, where Leonardo began his **water studies** in preparation for a water defense system for the city. Leonardo continued his water studies, in addition to his observations of birds in flight, throughout his life. After his return to Florence, he was hired by **Cesare Borgia** to design new fortifications and military technology, and he turned his attention to **cartography** while surveying papal territories. During this time, he drew both bird's eye and aerial views of Central Italy and the town of Imola in Northern Italy. Upon his return to Florence a year later, Leonardo expanded his water studies to devise a plan to divert the Arno River around Pisa and complete a treatise on water that would encompass the topics of fluid dynamics through various systems of hydraulic engineering. The majority of this work is gathered together in the ***Codex Leicester***.

Finally, Leonardo returned to his interest in aerial dynamics with extensive notes done in Florence that are gathered together in the ***Codex on the Flight of Birds***, which includes a prototype for a **flying machine** he intended to test out in the hills of Fiesole. In 1508,

Leonardo wrote notes on the dissection of an elderly man, and he expanded his anatomical studies five years later in **Rome**, where he arrived in 1513, upon the election of **Medici** pope **Leo X**.

In 1516, King **Francis I** invited Leonardo to France, where he was given a country estate near the royal Chateau d'Amboise. It was there that Leonardo died three years later, before assembling his sheets into the numerous treatises he planned to publish. His student, **Francesco Melzi**, inherited the notebooks and returned to his family villa outside Milan to organize and assemble them for eventual publication, although none of the notebooks were published. Upon Melzi's death in 1579, his heirs sold off the collection, and Pompeo Leoni, an Italian sculptor who worked for the king of Spain, acquired a large portion of the collection and disassembled Melzi's work to separate the scientific observations from the drawings in the original manuscripts. This proved to be an impossible task, and he lost some of the pages, while selling and donating other parts of the collection to patrons in Spain. His heirs brought the remaining collection back to Italy and sold it to Count Galeazzo Arconati, who donated the collection to the Biblioteca Ambrosiana in Milan in 1637. From there, Napoleon took the manuscripts to Paris in 1796, and in 1851, a portion of the collection was returned to Italy, while 12 of the manuscripts were kept in Paris.

Today, Leonardo's notebooks are organized in codices now held in the Louvre Museum in Paris, the Royal Library at Windsor, the Vatican Library, the Victoria and Albert Museum in London, the Biblioteca Ambrosiana in Milan, the Biblioteca Trivulziana in Milan, the Biblioteca Reale in Turin, the Institut de France in Paris, the British Library in London, the Biblioteca Nacional de España in Madrid, and the private collection of Bill Gates. These codices include the ***Codex Arundel***, ***Codex Ashburnham***, *Codex Atlanticus*, ***Codex Forster***, *Codex Leicester*, ***Madrid Codices***, *Codex on the Flight of Birds*, ***Codex Trivulzianus***, *Codex Urbinas*, and *Codices of the Institut de France*, while the Royal Collection Trust at Windsor holds approximately 600 unbound sheets. In addition to these notebooks, individual folios are in the collections of the Christ Church Picture Gallery in Oxford and the Accademia in **Venice**, while a *Trattato* by **Francesco di Giorgio Martini**, annotated by Leonardo, is in the Laurenziana in Florence. Individual drawings can also be found in the Accademia in Venice, including Leonardo's famous ***Vitruvian Man***. *See also* ARCHITECTURE, CLASSICISM, HUMANISM, INVENTIONS, MATHEMATICS; MUSEUMS, OPTICS; PERSPECTIVE; SCULPTURE; *TREATISE ON PAINTING*; VITRUVIUS, MARCUS POLLIO.

O

OCTANT PROJECTION. *See* WORLD MAP

OGGIONO, MARCO D' (c. 1470–1549). One of Leonardo's main students was Marco d'Oggiono, who was born in the town of his surname outside **Milan** to a local goldsmith. Although nothing is known of his early training, by 1490 d'Oggiono was documented as staying in Leonardo's house in Milan, where he was collaborating with a few of Leonardo's students. D'Oggiono then became an independent artist and worked in **Venice** before returning to Milan in 1504. The *Pala dei Tre Arcangeli*, in the Pinacoteca di Brera in Milan, early 1500s, is a good example of his style. Here, d'Oggiono depicts three elegant and richly colored angels banishing the devil into a pit located between them. An atmospheric landscape, in the tradition of Leonardo, recedes behind the figures, while clumps of foreground floral vegetation echoes Leonardo's careful attention to the small details of nature, although the sweet-faced figures lack the emotional connection of Leonardo's work.

D'Oggiono is best known as a prolific copier of Leonardo's **paintings**, including numerous versions of Leonardo's ***Last Supper*** and ***Virgin of the Rocks***. D'Oggiono's *Last Supper* painting (London, Burlington House) was consulted during the renovation of Leonardo's *Last Supper* mural in the 1980s, and if Leonardo's mural had been fully destroyed during World War II, d'Oggiono's version would have been the best document of Leonardo's original work. *See also* ATMOSPHERIC PERSPECTIVE; LEONARDESCHI.

OIL. Oil paint is made of pigments from organic and inorganic matter that are ground into a powder and suspended in an oily binding agent, like linseed oil. During the **Renaissance**, **colors** were primarily made of earth or mineral pigments with some biological matter. Oil paint was rare prior to the 1400s, and most color powders were mixed with water or egg in a process of **fresco** or **tempera** painting. By the 1400s, more artists had begun to experiment with oil paint, most famously Flemish painter Jan van Eyck (c. 1390–1441), who worked in Bruges and was known for his luminous, detailed realism. Oil pigments are more brilliant and translucent than tempera paints, and they allow for a greater variety of color variation.

Van Eyck's use of shimmering colors became known in Italy, and one of the earliest Italian painters to introduce the use of oil was **Antonello da Messina**, who studied the Flemish technique in Naples during the rule of King Alfonso V of Aragon, who favored Northern European art and amassed a collection of Flemish **paintings** in Naples. Leonardo would have been introduced to Antonello's work either in **Milan** or **Venice**, where Antonello lived in the mid-1470s before returning to his hometown of Messina. Oil is thicker than water or egg, therefore, it dries more slowly and might crack. While van Eyck heated his oil mixture with ground bone and glass, added to the pigment to make it more viscous, Antonello improved this "cooked oil" recipe with the addition of lead oxide so the pigments had a consistency of honey, which allowed them to dry more evenly without cracking. The colors

were then applied in thin layers called glazes that increased their color depth and richness, and could be blended in half tones of shading and shadowing, creating the effect of soft **light**. Leonardo adjusted the cooking times to heat the oil at lower temperatures and added beeswax to stabilize his pigments to prevent their darkening. Venetian artists Giorgione (c. 1477–1510) and Titian (c. 1488–1576), who were familiar with some **chemistry** through the Venetian glass industry, experimented with more recipe variations during the early 1500s.

As a scientist, Leonardo experimented with a wide variety of new media, and in many instances, his experiments were not successful. For example, Leonardo struggled with his ***Battle of Anghiari*** wall mural, commissioned in 1503, and was excused from the commission in 1506, after his intonaco failed and his oil paint dripped down the walls. Scientific analysis has shown that Leonardo attempted to use a wider variety of pigments, including azurite mixed with a walnut or linseed oil, on an experimental encaustic from antiquity called Greek pitch, which was applied to the plaster wall. Unlike the watery, fresco pigments, oil paint does not soak into plaster but remains on the surface. Leonardo attempted to warm the wall surface with a brazier to dry the paint, but that only increased the dripping. Leonardo also used oil in his ***Last Supper***, which he painted on a dry wall rather than on the damp plaster used in the fresco technique. Here he primed the wall like a wood panel and used a mixture of tempera and oil paint to achieve the subtle color gradations and atmospheric qualities of his panel paintings

This oil technique was not entirely new, but was described by Cennino Cennini (c. 1360-c. 1427), in his *Libro dell'arte*, written in about 1400. While Cennini noted that a fresco could be touched up with oil accents once it was dry, Leonardo covered the entire dry wall with oil paint, which never adhered correctly due to the humidity, and it was already flaking off by the early 1500s. Leonardo's use of oil-on-wood panel, however, was highly successful, and this material generated a new technique that allowed for his characteristic **sfumato** as well as his more subtly graded **atmospheric perspective**. *See also* BELLINI, GIOVANNI.

OPTICS. Leonardo's studies in optics grew out of his broad interests in the physical world, but more specifically from his study of **light** and mathematical **perspective**, needed to depict objects realistically in his **paintings** and **drawings**. Optics refers to the scientific examination of the behavior of light, and artists are often interested in knowing how light is perceived by the human eye and how sensory data is interpreted by the viewer to more accurately represent the physica world in a pictorial format. Leonardo sought to examine the world with his own eyes and compare his sensory data with what had been written by Ptolemy, Galen, and others in antiquity. These comparisons led him to reject previous ideas and form a new understanding of how light, perspective, and reflection affected vision. His optical studies are bound together with his studies of **astronomy**, which gave him a more sophisticated understanding of light and shadow, as well as luminescence.

While in **Milan**, he began to study **Leon Battista Alberti's** optical studies and found conflicting observations that led him instead to the work of Alhazen (Ibn al-Haytham) (c. 965–c. 1040), whose seven-volume *Book of Optics* from c. 1020 was translated into **Latin** a century later and introduced into Europe in the Early **Renaissance**. Alhazen studied the human eye and experimented with lenses and mirrors to better understand vision, and his ideas influenced the optical studies of John Peckham (c. 1230–1292). Leonardo owned a copy of Peckham's optical study *Perspectiva Communis* and perhaps arrived at his own optical studies in consultation with **Fazio Cardano** in Milan. *See also* ANAMORPHOSIS; ATMOSPHERIC PERSPECTIVE, CLASSICISM; HUMANISM; LINEAR PERSPECTIVE; MATHEMATICS, PACIOLI, LUCA

ORNITHOPTER. *See* AERODYNAMICS, *CODEX ON THE FLIGHT OF BIRDS*; INVENTIONS.

P

PACIOLI, LUCA (c. 1447–1517). Fra Luca Bartolomeo de Pacioli was a Franciscan mathematician known for his contributions to the field of accounting. He published the first book on double-entry bookkeeping, with columns for debits and credits. Prior to the French invasion of **Milan** in 1499, Italian architect Giacomo Andrea from Ferrara had translated parts of **Vitruvius's** treatise on architecture for Leonardo, and Leonardo had also met Pacioli in Milan during that same decade. It is thought that Leonardo learned **geometry** from Pacioli, and Leonardo was instrumental in helping Pacioli obtain a teaching position in Milan. Pacioli also helped Leonardo create a **perspective** system for his ***Last Supper***. In late 1499, Pacioli and Leonardo left Milan together, going first to **Mantua**, then **Venice**, and arriving in **Florence** in the spring of 1500.

Back in Milan in 1509, they collaborated on Pacioli's *De Divina Proportione*, where Leonardo used **Renaissance** theories of perspective and proportion to create realistic and aesthetically beautiful works of art. Leonardo made about 60 illustrations for *De Divina Proportione*, examining the relationship between geometry and **architecture**. Leonardo's interest in **mathematics** was focused on geometry, and it was for this treatise that Leonardo drew his famous ***Vitruvian Man***, which measured the proportions of the human body inside a square and a circle. *See also* LINEAR PERSPECTIVE; OPTICS.

PAINTINGS. Although Leonardo is known primarily as a painter, his **notebooks** reveal a man deeply engaged in scientific observation whose sketches number in the thousands, while about 15 to 23 paintings are universally attributed to him. Several more paintings have been attributed to him recently, although scholars are not in agreement on the majority of these works. Scholars initially thought such new technical advances as fingerprint analysis and other microscopic data would help clarify Leonardo's extant oeuvre, but these results remain ambiguous, while a push to confirm recent attributions like the ***Salvator Mundi*** appear to be motivated by large sums of money, which has helped fund multiyear in-depth research groups and promotional publications, leading to higher purchase prices.

Nonetheless, writers like **Giorgio Vasari** mentioned numerous works by Leonardo, which are lost today, so it is possible that more original Leonardo works could be identified in the future. Original attributions are complicated by the fact that Leonardo's students were trained to paint in his style, and many copies were made of his paintings both in his lifetime and afterward, and it was also common for an artist and his assistants to collaborate on a painting. Furthermore, some works have been damaged or overpainted, which makes such identifications more difficult.

Leonardo painted primarily on poplar or walnut panels using a mixture of **oil** and **tempera** paints, while he also painted several murals using oils. Thus, none of them were in the true **fresco** technique. Two works, his ***Adoration of the Magi*** and ***Saint Jerome in the Wilderness***, remain unfinished, while one

large cartoon is extant. He also never signed any of his works, although some are mentioned in archival documents of the era. The first work most scholars agree reveals Leonardo's input is **Andrea del Verrocchio's** *Baptism of Christ*, from between 1469–1476, while the first painting thought to be Leonardo's earliest independent work is his ***Annunciation***, from 1472–1476. Leonardo painted several Madonna and Child images and female **portraits**. Two works are on paper, the ***Virgin and Child with Saint Anne and Saint John the Baptist***, known as the *Burlington Cartoon*, and the more recently discovered ***Portrait of Isabella d'Este***. His two murals include the famous ***Last Supper*** and the ***Sala delle Asse*** wall fragments, while an oil-on-walnut painting of ***Saint John the Baptist*** is considered Leonardo's last known work.

Finally, many paintings by Leonardo's students and followers, who are called the **Leonardeschi**, are similar in style to Leonardo's work, while some works, for example, **Giovanni Ambrogio de Predis's** *Portrait of a Lady in Profile*, from c. 1495, are thought to show the hand of Leonardo. We will likely never confirm Leonardo's entire career with certainty, but we have been able to better understand the cultural orbit in which Leonardo worked in the **Renaissance**. *See also* CLASSICISM; HUMANISM; LANDSCAPES.

PAINTINGS OF LEONARDO. Leonardo was not only well known in Western Europe during his lifetime, but also his fame has endured uninterrupted since then, with many artists echoing **Giorgio Vasari's** assessment of Leonardo's importance in his *Vite*, published in 1550. Leonardo's **paintings** are primarily on display in Italy, where he spent most of his career, and in France, where he spent the last three years of his life. Numerous artists have memorialized Leonardo in their own art, including Angelika Kauffmann (1741–1807), in her large painting entitled *Leonardo Dying in the Arms of Francis I*, from 1778, which is the first known example of this popular subject. Kauffmann was a Swiss Neoclassical painter who worked primarily in **Rome** and London, and exhibited this painting at the Royal Academy's annual exhibit. This subject promotes Vasari's story that **Francis I**, king of France, was present at Leonardo's death, and it romanticizes the friendship between Leonardo and the king in an image that likely exaggerated the informality between artist and patron.

This subject became popular among French artists of the 18th century, who understood that Leonardo's paintings were some of the earliest to form the royal collection of art on public display in France. Upon Leonardo's death in 1519, several of his paintings entered the collection of Francis I and were first housed at the Palace of Fontainebleau and later in the Louvre Museum in Paris, which has five of Leonardo's best-known paintings today. The ***Mona Lisa***, for example, has been on display at the Louvre since 1797, four years after the Louvre opened to the public. Leonardo's art was therefore highly accessible by the early 1800s, when we find several French Neoclassical and Romantic artists who painted **portraits** of Leonardo and historical scenes from Leonardo's life. Indeed, during this era, painting was often characterized by a nostalgic reframing of the history of artists from the **Renaissance**.

French painter Francois-Guillaume Ménageot (1744–1816) painted the same subject as Kauffmann in 1781 (9.1 x 11.7 feet, **oil** on canvas, Amboise, Musée de l'Hôtel de Ville), while Jean-Auguste-Dominique Ingres (1780–1867) painted a version of *Francis I of France Receiving the Last Breath of Leonardo da Vinci* in 1818, which shows another dramatic image of Leonardo on his deathbed, being watched over by King Francis I (15.7 x 19.8 in., oil on canvas, Paris, Petit Palais). Commissioned by the French ambassador in Rome, here we see the king seated on Leonardo's bed, hovering over him and holding him. Leonardo's head leans back on the pillow with his long, flowing white beard, which resembles several known **drawings** of Leonardo. Finally, Italian Neoclassical sculptor Luigi Pampaloni (1791–1847) carved **sculptures** of several Italian Renaissance artists, including a full-length niche figure of Leonardo holding a notebook and wearing an artist's cap, located outside the Uffizi Gallery in **Florence**. *See also* MUSEUMS.

Jean-Auguste-Dominique Ingres, *Francis I Receiving the Last Breath of Leonardo da Vinci*, 1818, oil on canvas, 15.7 x 19.8 inches, Paris, Petit Palais

PALEONTOLOGY. *See* CARTOGRAPHY; GEOLOGY; ICHNOLOGY.

PARACHUTE. One of Leonardo's best-known **inventions** was his parachute, which appears in an annotated sketch in the ***Codex Atlanticus***, fol. 1058v. Here we see a man hanging from a pyramidal frame covered with linen. The frame would have consisted of wood poles about 23 feet wide and deep at the square base and coming together at the top, with waterproof linen bolted onto the frame much like how canvas is stretched onto a painting frame. The person would then hold onto the bottom of the frame, not attached to a harness. Contemporary tests would have been limited to trees, short towers, and some of the smaller cliffs around Tuscany, and no documents detail these flying experiments. Next to the sketch, Leonardo wrote that if a man has a tent made of linen with no openings except at the bottom, he can throw himself down from great heights without injury.

A foldable parachute was invented by Sebastien Lenormand in 1783, and the harness was introduced in the 19th century. In 1920, the modern parachute, folded up and attached to a ripcord, was introduced. Modern scholars have recreated many of Leonardo's inventions, and in 2000, skydiver Adrian Nichols tested Leonardo's design, which appeared to be functional, except for its heavy weight, which could possibly bear down on the jumper at landing, risking injury. *See also* AERODYNAMICS; *CODEX ON THE FLIGHT OF BIRDS*; FLYING MACHINES; NOTEBOOKS.

PARIS MANUSCRIPTS. **Francesco Melzi** inherited Leonardo's **notebooks** upon the artist's death, and after Melzi died in 1579, his heirs disassembled the notebooks and dispersed them throughout Europe. Pompeo Leoni (1533–1608) bought a large portion of the collection and rearranged, donated, lost, or sold parts of it during his time in the court of the king of Spain. Leoni sought to extract the **drawings** from the scientific observations, and upon Leoni's death, his heirs sold the remaining manuscripts to Count Galeazzo Arconati in **Milan**, who donated them to the Biblioteca Ambrosiana in 1637. In 1796, Napoleon took the manuscripts to Paris, and while some of the sheets were returned to Milan, 12 were kept in Paris and numbered alphabetically from A through M, excluding J. These folios are located in the Institute de France in Paris and bound in either parchment or leather by size. They are also called the *Codices of the Institut de France*. The smallest is *Codex M* (4 x 2.7 in.), while the largest is *Codex C* (12.2 x 8.7 in.), while the earliest dated manuscript is Manuscript B from c. 1485–1487, and the latest is Manuscript E, dated 1513–1514.

Like all of Leonardo's notebooks, subjects range from optical studies, to **geometry**, to military **engineering**, to birds in flight, to **hydraulics**. Manuscript A (c. 1492) is part of a larger notebook that originally included the ***Codex Ashburnham* II** and provides discussions of **perspective**, mechanics, and **water studies**. Leonardo's famous **helicopter** and **submarine**, as well as his designs for centrally planned churches, are found in Manuscript B (c. 1488–1490, 84 folios), while Manuscript C (c. 1490–1491, 28 folios) has Leonardo's treatise on **light** and shade. Leonardo's ***Codex on the Flight of Birds*** was originally part of Manuscript B and is now located in the Biblioteca Reale in Turin. Manuscript D (1508–1509, 10 folios) includes drawings and a discussion of vision, while Manuscript E (1513–1514, c.

96 folios) includes Leonardo's invention for draining the Pontine Marshes outside of **Rome** and studies of birds in flight and gravity. Manuscript F (1508–1513, 96 folios) includes discussion of **geology** and **astronomy**, as well as water and **optics**. Manuscript G (1510–1515, 93 folios) is focused on botany. Manuscript H (1493–1494, 142 folios) consists of three small notebooks bound together that primarily focus on Euclidean geometry. Manuscript I (1497–1505), 139 folios) consists of two small pocket notebooks that include a list of **Latin** words and notes on geometry, perspective, and proportions. Manuscript K (1503–1508, 128 folios) includes three pocket notebooks primarily on geometry, while Manuscript L (1497–1502, 94 folios) is one larger notebook on military engineering, used by Leonardo while working for **Cesare Borgia**. Finally, Manuscript M (c. 1497–1500, 48 folios) is a pocket notebook on geometry, military engineering, and **botanical studies**. *See also* MATHEMATICS.

PEDRETTI, CARLO (1928–2018). Italian Leonardo specialist Carlo Pedretti was professor emeritus of art history and Armand Hammer Chair in Leonardo Studies at the University of California, Los Angeles, but he lived in **Vinci**, where he continued his research until his death in 2018. Pedretti published more extensively on Leonardo throughout his long career than any other art historian, with more than 50 books and 700 articles on Leonardo, while he also curated numerous exhibitions and was regularly consulted on issues of attribution. His monograph on Leonardo, one of many, is considered the best discussion of the artist's career, while his research on Leonardo's codices has led to the publication of several of them in facsimile editions, making them widely available to the public. Pedretti teamed up with contemporary artists to recreate many of Leonardo's inventions.

Pedretti's contributions also included his extensive work on Leonardo's codices, where he identified Leonardo's ***Treatise on Painting***, which was published as *Leonardo Da Vinci on Painting. A Lost Book* (*Libro A*) (1964). Next, Pedretti returned to the monographic format in his *Leonardo: A Study in Chronology and Style* (1973), where his assessment of Leonardo's contributions remains the most astute in modern scholarship. Pedretti also published a series of studies on Leonardo's **drawings**, one of which was *Leonardo da Vinci. Nature Studies from the Royal Library at Windsor Castle* (1982). Moreover, he sought to bring together Leonardo's scientific contributions with his art in *Leonardo: Art and Science* (2000). One final publication was a collection of essays written in his honor by his students, entitled *Illuminating Leonardo. A Festschrift for Carlo Pedretti Celebrating His 70 Years of Scholarship (1944–2014)* (ed. Constance Moffatt and Sara Taglialagamba, Leiden: Brill, 2016), which commemorates Pedretti's extensive career in art history. *See also* CLARK, KENNETH MACKENZIE, *CODEX ARUNDEL*; *CODEX LEICESTER*; KEMP, MARTIN, *MARY MAGDALENE*, NOTEBOOKS.

PERSPECTIVE. Perspective is the technique of rendering three-dimensional objects on a two-dimensional surface. Artists learned two types of perspective in the **Renaissance** that allowed them to create more naturalistic examples of three-dimensional space expressed on a two-dimensional surface—**linear perspective** and **atmospheric perspective**, also called aerial perspective. Leonardo began a study of perspective early in his career as a way of better understanding how distance affects the appearance of objects, including their **color** and scale, and he used these perspective studies in both his artistic and scientific interests. These perspective studies had their origins in the ancient study of **optics**, while Renaissance artists built on these studies with examinations of the physical properties of the eye and the pictorial representation of space. *See also* MATHEMATICS, *MONA LISA*, NOTEBOOKS; OPTICS; *PARIS MANUSCRIPTS*; PIERO DELLA FRANCESCA, *TREATISE ON PAINTING*; UCCELLO, PAOLO.

PHYSIOLOGY. Physiology is a branch of biology focused on how living organisms function and interact. The word is Ancient Greek and refers to the study of nature. Physiological

studies first appeared in antiquity and were initially focused on the human body for the purpose of studying medicine. Greek physician Hippocrates (c. 460–c. 370 BCE) was instrumental in the establishment of this discipline and is considered a foundational figure in the history of medicine. His studies of the human body allowed him to advance the notion that disease occurred naturally in the body as a pathological reaction to normal functioning rather than as a curse of punishment from the gods, and from his studies early scholars began to separate religion and science.

Ancient Chinese and Indian physiological studies were perhaps more advanced than Greek ideas at the time, but those were not as widely available in Western Europe during the **Renaissance**, with the exception of Islamic scholars like Ibn al-Nafis (1213–1288) from Damascus, who sought to write a comprehensive encyclopedia on medicine, which he completed to 80 volumes by the time of his death. His more famous treatise is on the circulatory system where he challenged ancient sources and instead advanced medical theories based on more scientific studies of **anatomy** and physiology. His studies of the human body were limited by his religious beliefs against human dissections, but he would have been able to examine the functions of the human body, for instance, the pumping of the heart, during surgical procedures, thereby allowing him a fuller understanding of the physiological nature of the human body. His ideas would have been known in Italy at some point during the late Middle Ages and certainly eventually through the travels of Andrea Alpago (c. 1450–c. 1522), an Italian physician who worked in Damascus for the Venetian consulate, before returning to Italy in 1500, where he received a teaching position at the University of Padua just before his death.

While Hippocrates and Aristotle ascribed to the theory of the four humors, an idea still prevalent in the Renaissance, later Greek physician Claudius Galenus of Pergamon, known as Galen (129–c. 210 A.D.), was the most influential ancient Western scholar on Renaissance anatomy and physiology. After settling in **Rome**, Galen used direct observation in his animal dissections to advance physiological theories like those on the circulatory system, but his studies were limited since he never dissected a human body. Nonetheless, he devised a theory that the body is connected by three systems: the brain and nerves, which give thoughts and sensations, the heart, which beats life into the arteries; and the liver and veins, which nourish and cleanse the body. Because of these observations Galen is acknowledged as the founder of the discipline of physiology, and his ideas remained relevant until the Renaissance, when the word *physiology* was first used by French physician Jean Fernel (1497–1558).

Fernel worked for the royal court in Paris and gave medical advice to Catherine de' **Medici**, the wife of king Henry II of France, while he also wrote a treatise called *Universa Medicina*, which included chapters on "physiologia," "pathologia," and "therapeutice." Leonardo's most important anatomical studies were done later in his life, after the 1500s, and included, most notably the dissection of an elderly man in 1506, where he first observed atherosclerosis. He also made a glass model of an aorta where he poured water with seeds into it to observe the fluid moving through the aortic valve. *See also* CLASSICISM; HUMANISM; NOTEBOOKS; WATER STUDIES.

PIERO DELLA FRANCESCA (c. 1415–1492). Piero della Francesca was an Early Italian **Renaissance** painter known for his mathematical interests. He was born in the small hamlet of Borgo San Sepolcro, in the territory of **Florence**, to a merchant and his wife, who was a member of the noble Monterchi family. One of Piero's commissions was for a *Madonna del Parto* **fresco** in the small communal church of Santa Maria di Momentana in Monterchi, from c. 1459. Piero was apprenticed to a local painter in the 1430s, and in 1439, documents show he was working at the church of Sant'Egidio in Florence on a now-lost fresco. While in Florence, Piero would certainly have seen the frescoes of Giotto di Bondone (c. 1267–1337) and **Masaccio**, both of whom introduced a new sense of naturalism, space, and depth in their narratives.

Piero's style, seen in his *Baptism of Christ*, c. 1450 (London, National Gallery), is characterized by a classical restraint, balance, symmetry, and the use of **geometry** to organize his compositions. Here, Christ stands in a shallow pool of water, dried out at his feet, while John the Baptist reaches over to pour water on his head while a white dove hovers above. Angels stand to the viewer's left, tucked behind a tree, which echoes the columnar pose of Christ. The calm, quiet tone suggests a sense of permanence in contrast to the desire for movement seen in the work of Piero's contemporary, **Antonio del Pollaiuolo**. Piero's most famous commission was his fresco cycle of the Legend of the True Cross, painted over the high altar of the church of San Francesco in Arezzo from the 1450s, after which Piero traveled to Urbino to work for the count, then duke, Federico da Montefeltro, who maintained a vibrant courtly culture and one of the largest libraries in Europe. There Piero met Flemish painters, Tuscan artists, mathematician **Luca Pacioli**, and perhaps also **Leon Battista Alberti**.

Piero studied **mathematics** throughout his life. He first received a basic education in arithmetic, which was part of the curriculum needed for merchants. Later, he wrote three treatises on mathematics, the *Trattato d'Abaco* (*Abacus Treatise*), the *Libellus de Quinque Corporibus Regularibus* (*Book on Five Regular Solids*), and his most famous book, *De Prospectiva Pingendi* (*On Perspective in Painting*). *De Prospectiva*, begun in about 1474, is the earliest Renaissance treatise written exclusively about **perspective**, and it is organized into three chapters, on design, depth, and **color**. In this way, artists could learn how to draw complex, three-dimensional shapes in a convincing realism that allowed for exact measurements of size and shape. Piero's studies were built on the mathematical perspective system codified by Alberti in his treatise *De pictura*, from 1435, and he also looked back to Euclid's original studies on the subject. His interest in solid geometry and perspective also influenced Pacioli, who, in turn, tutored Leonardo in these concepts, as found in Pacioli's *De divina proportione*, illustrated by Leonardo. *See also* ARCHITECTURE, GHIRLANDAIO, DOMENICO; LINEAR PERSPECTIVE; MICHELANGELO BUONARROTI.

PLATE TECTONICS. *See CODEX LEICESTER*; GEOLOGY.

PLATO. *See* CHEMISTRY; CLASSICISM, CORVINUS, MATTHIAS; FICINO, MARSILIO; FLORENCE; GEOMETRY, HUMANISM; MUSIC; MIRANDOLA, GIOVANNI PICO DELLA; POLIZIANO, ANGELO.

PLATONIC ACADEMY. The Platonic Academy in the **Renaissance** was an informal group that gathered together in **Florence** to discuss the ideas of Plato. It was established by Cosimo de' **Medici** to emulate the original academy established by Plato (c. 428 BCE–c. 387 BCE) in Athens. Aristotle trained there and founded another school, called the Lyceum. These schools ended during the Roman Empire but were revived periodically through the Middle Ages. With this mode of learning, the instructor would propose ideas that could be debated in an informal dialog on a variety of subjects.

Cosimo knew the importance of education for the noble class, and through his patronage he sought to elevate the knowledge base in Florence as a demonstration of their cultural superiority. The first instructor of the Platonic Academy was Gemistus Pletho (c. 1355–c. 1452), a Greek scholar from Constantinople who came to the Council of Florence in 1438, as an ambassador to help reconcile the East–West Catholic schism. He introduced the Medici to the importance of Plato's ideas in classical thought, and soon thereafter, the Medici founded this new institution under the direction of humanist scholar **Marsilio Ficino**, who translated Plato's works into Latin.

The academy ended with the death of Lorenzo de' Medici in 1492, and two years later, both Ficino and humanist **Giovanni Pico della Mirandola** died. **Michelangelo** was personally involved in the Platonic Academy, and Leonardo, who was also sponsored by the Medici, and was likely a guest at academy events. This deep interest in classical philosophy in Florence in the 1400s pervaded the art culture and influenced the ideas of many artists.

The Platonic Academy was an important resource in providing access to classical texts in both Latin and the vernacular Italian. *See also* ASTRONOMY; BOTTICELLI, SANDRO; CATHOLICISM; CLASSICISM, MUSIC; PAINTINGS; POLIZIANO, ANGELO.

POLIZIANO, ANGELO (1454–1494). Angelo Poliziano was a **Renaissance** humanist contemporary to Leonardo who influenced philosophical ideas in **Florence** in the second half of the 1400s. Born in the Tuscan borgo of Montepulciano, his father was murdered when Poliziano was 10 years old for supporting **Medici** expansion into Montepulciano, so the young boy was then sent to Florence to live with a cousin and study with **Marsilio Ficino**. He was patronized by the Medici family, and served as a tutor to their children, while Lorenzo de' Medici gave him a position at the University of Florence, and he also provided lectures at the **Platonic Academy**, which was held at the Medici Villa at Careggi. There, he was known for his breadth of knowledge on antiquity, and he offered analyses and opinions, while also correcting prior translation errors. He is best known for his translation of Homer's *Iliad* into **Latin**, as well as his published edition of the poetry of ancient Roman writer Catullus, who favored vernacular rather than historical poetry. He lived at a time when classical writings were being assimilated into intellectual culture, and his accuracy of translation and scholarly annotations provided a firmer historical context for the study of philosophy.

In 1480, Poliziano traveled to **Mantua** as a guest of Cardinal Francesco Gonzaga, and there he wrote the *Favola di Orfeo*, the first example of a secular theater performance written in the vulgare. Leonardo would have been familiar with the performance of Orpheus from Ovid's *Metamorphosis* and in Dante's *Convivio*, and Ficino further argued that this story confirms a poet's ability to avoid violence through beauty. In 1480, Leonardo was living with the Medici in Florence, and at some point in his career, he drew a series of sketches of the stage set for this performance, now found in the ***Codex Atlanticus***, where he notes that his drawings are for the scene "Quando B s'abbassa A si alza e Pluton esce in H." This perhaps refers to the scenes where one of the Argonauts, Boutes, is so enchanted by the **music** of Orpheus that he jumps into the water and is saved by Aphrodite, the Greek goddess of love and beauty, while Pluto descends into the underworld. Leonardo continued to work in stage design and performance production for **Lodovico Sforza** in **Milan**, where he would have had to continue his studies of classical theater. *See also* CLASSICISM, HUMANISM; MIRANDOLA, GIOVANNI PICO DELLA.

POLLAIUOLO, ANTONIO DEL (1431/1433–1498). Italian **Renaissance** goldsmith Antonio del Pollaiuolo was born in **Florence** and trained in both painting and **sculpture**. He was a contemporary of **Andrea del Verrocchio**, and both artists were interested in realism and anatomical study during the mid-1400s. Both artists worked in bronze sculpture, and while Verrocchio cast large monuments, for example, his equestrian figure of Bartolomeo Colleoni from 1475, in **Venice**, Pollaiuolo introduced the small statuette, a new type of art object revived from antiquity that provided additional opportunities for merchant class patrons and private, secular settings. Pollaiuolo's *Hercules and Antaeus*, a bronze statuette from c. 1475 that is 18 inches tall (Florence, Bargello Museum), reveals his interest in the exaggerated, even contorted, poses possible with the human body. His works show the tense muscles and tendons needed for holding different types of poses and gestures.

Pollaiuolo's engraving entitled *Battle of Ten Nudes*, from before 1470 (Cleveland, Cleveland Museum of Art), is a study in dramatic posing, where nude men twist and turn in space, attack, and fall to the ground. Engravings allow for multiple copies to be done on paper, which are more easily disseminated to a broader public. Leonardo certainly would have been aware of Pollaiuolo's work in Florence through both his artistic output and the fact that Pollaiuolo's Florentine workshop was second to Verrocchio's in size and importance from the 1460s through the 1480s.

Giorgio Vasari also noted that Pollaiuolo was the first artist in Florence to dissect

human corpses sometime in the mid-1400s, and it is likely that Leonardo followed in Pollaiuolo's footsteps by cultivating connections in Florence, where he would have access to human corpses for the purpose of dissection. The Catholic Church did not allow human dissections during this time, which severely limited opportunities to study human anatomy, and so most early studies were done in secret. It was not until the mid-1500s that dissections were widely practiced to the benefit of both art and science. Pollaiuolo was one of the main artists who established the precedent for these later studies.

Leonardo continued his dissections in **Milan**, and his anatomical studies eventually surpassed that of Pollaiuolo in his use of shading and shadowing to create more realistic details. Leonardo criticized artists who showed all muscles flexed at the same time to promote their own artistic skills over natural observation, and that criticism was likely directed at Pollaiuolo; nonetheless, many of Leonardo's **drawings** reveal similar postures and gestures, as found in Pollaiuolo's drawings and sculptures. Like Pollaiuolo, Leonardo sought to depict his figures from multiple viewpoints to show what he called their "true nature." *See also* ANATOMY, BOTTICELLI, SANDRO; CASTAGNO, ANDREA DEL; CATHOLICISM; GHIBERTI, LORENZO, GHIRLANDAIO, DOMENICO, PAINTINGS, UCCELLO, PAOLO.

POLYHEDRON. *See* GEOMETRY; MATHEMATICS; PACIOLI, LUCA.

POLYMATH Leonardo is often called a polymath, which refers to a person with a wide range of knowledge in a variety of subjects. The word is originally Greek, and it describes a person who has learned much, while in **Latin** this type of person is considered a "universal man." The term was first used in 1603, by the German philosopher Johann von Wower, so Leonardo was not described in this way during his lifetime, although the concept of a widely learned person was discussed by such contemporary humanists as **Leon Battista Alberti**.

Alberti was informed by humanist thought in his notion that humans should seek to better themselves through education. During the **Renaissance**, education was not divided into specific areas of study, but rather was loosely separated into the classical and applied areas of study. University students studied Latin and classical literature, law, medicine, philosophy, and science. Arithmetic became increasingly important for the mercantile class, while **geometry** was both applied and abstract. **Astronomy** was an important field of study, as were the related fields of **music** and poetry. What made Leonardo unique was his ability to bring together the applied disciplines and his scientific observation with his artistic skills to advance universal knowledge. *See also* ANATOMY, ANIMAL STUDIES, ARCHITECTURE; BOTANICAL STUDIES, CARTOGRAPHY; CHEMISTRY; COPERNICUS, NICOLAUS, DÜRER, ALBRECHT, ENGINEERING; GALILEI, GALILEO, GEOLOGY; INVENTIONS, MATHEMATICS, OPTICS; WATER STUDIES.

PONTINE MARSHES. *See* ROME.

PORTRAIT OF ISABELLA D'ESTE. Isabella d'Este (1474–1539) was the Marchesa of **Mantua**; the wife of Francesco I Gonzaga; and the sister of Beatrice d'Este, who was married to Duke **Lodovico Sforza** of **Milan**. Leonardo met Isabella in 1499, when he fled the French advance into Milan and was invited to stay in the Ducal Palace in Mantua, together with mathematician **Luca Pacioli**. There, Isabella commissioned Leonardo to paint her portrait, and although the painting was never done, Leonardo executed a beautifully detailed preparatory sketch that shows her head in profile with her torso angled toward the viewer. This drawing is done in red, black charcoal, white, and yellow ochre chalk (not pastel, as is often assumed), which Leonardo drew and smudged to create subtle modeling of Isabella's face and hair (c. 1500, 24.8 x 18 in., paper, Paris, Louvre Museum).

Documents show that Isabella initially hoped to invite both Leonardo and Venetian artist **Giovanni Bellini** to paint her portrait and she would select a winner, but this competition never materialized. This preparatory

drawing is the second, more finished drawing, and it is all that remains of the commission. The first drawing, an initial sketch, was left in Mantua and is now lost, while Leonardo took this second drawing to **Venice**, where it was described in a letter written to Isabella in 1500. This drawing has needle holes punched into parts of the outlines, which would suggest it was being prepared for pouncing, or dusting onto a wood panel. The sketch also reveals a new format where the profile view could have been requested by Isabella, which Leonardo modified with the frontally posed torso as if he had taken his earlier portrait, ***Lady with an Ermine***, and pivoted the entire figure of Cecilia Gallerani on an axis so the profile is more of a three-quarter view while the torso faces left instead of right. Isabella's arms remain unresolved in the drawing, however, where her right hand suddenly arrives at the lower front edge of the drawing by a dramatically foreshortened forearm that emerges from the billowing sleeve of her upper arm. The crowded right arm is mitigated by the left arm, however, which stretches across the lower frame of the composition as if resting on a ledge.

Isabella maintained a vibrant court in Mantua and served as regent when her husband was out of town. She grew up in the court of Ferrara and in Naples, and was educated in **humanism** and the arts. Her life is well documented via the huge number of letters she wrote to family and friends throughout her life. At the age of 15, she married Francesco Gonzaga and eventually had eight children, while at the same time she was allowed the freedom to travel and oversee the courtly culture of Mantua. She was also considered an able political leader in her husband's absence and after his death, when Isabella was 45 years old.

In 2015, a painting identified as a portrait of Isabella d'Este was seized from a bank vault in Lugano, Switzerland, after a lawyer in Pesaro had been contacted in 2013, to assist with a quiet sale of this painting, attributed to Leonardo da Vinci. **Carlo Pedretti** identified the painting as the finished work of Leonardo's drawing of Isabella, and indeed, the profile view, face, gesture, clothing, and overal composition are the same. **Martin Kemp** doubted this claim, however, and while the drawing reveals a subtle mastery of modeling and realistic detail, the finished painting appears to be a copy made by another **Renaissance** artist based on Leonardo's drawing. Carbon dating reveals the painting to be from the early 1500s, but it was made on canvas, which Leonardo never used. Further forensic research on the painting will hopefully resolve its attribution. *See also* *BELLA PRINCIPESSA*; *BELLE FERRONNIÈRE*; *GINEVRA DE' BENCI*; LEONARDESCHI, *MONA LISA*, PAINTINGS; PORTRAITS.

PORTRAIT OF A LADY IN PROFILE. *Portrait of a Lady in Profile*, an **oil**-on-panel painting in the Pinacoteca Ambrosiana in **Milan**, is sometimes attributed to Leonardo and perhaps a portrait of Beatrice d'Este. Measuring 20 x 13.3 inches, the portrait dates to between 1485–1500, and is similar in its profile pose to ***Bella Principessa***, which has recently been attributed to Leonardo. This painting is more frequently attributed to Leonardo's Milanese apprentice, **Giovanni Ambrogio de Predis**, however, who is also credited with painting the ***Portrait of a Musician***, also at times attributed to Leonardo.

Here we see a long woman in profile set against a black background. The black background has never appeared in Leonardo's securely attributed works but was characteristic of de Predis's portraiture. The woman wears an elegant red dress and black shawl encrusted with large gems, and her reddish-brown hair, painted in highly realistic detail, is loosely tied together in a woven head covering with a leather strap encrusted with jewels, pulled across her forehand and attached with a ribbon on the side. This type of hairstyle was popular in the Milanese court during this time. The young woman's face is softly modeled with plump cheeks and rich red lips, while her slightly upturned nose and round chin confirm the work as an individual portrait.

Beatrice d'Este (1475–1497), the wife of Duke **Lodovico Sforza**, was considered one of the most beautiful women in Milan and the sister of Isabella d'Este. Both sisters were known for their elegant clothing and inventive hair styles. In 1491, Beatrice married Lodovico, while her

brother, Alfonso d'Este, married Lodovico's niece, Anna Sforza, in a double wedding organized by Leonardo Leonardo and his assistant, de Predis, would certainly have known Beatrice, and this could be a wedding portrait. *See also BELLE FERRONNIÈRE; GINEVRA DE' BENCI; MONA LISA*, PAINTINGS; PORTRAITS.

PORTRAIT OF A MAN IN RED CHALK. This red chalk drawing on paper from about 1512 (13 x 8.5 in., Turin, Biblioteca Reale), is generally attributed to Leonardo and considered a self-portrait at about age 60. Although this famous drawing has given viewers a lasting image of Leonardo as an elderly man with a long beard, its identification has been questioned. This image is a bust-length, slightly three-quarter view portrait that represents an older man than **Francesco Melzi's** red chalk profile drawing of Leonardo in the Royal Library in London, which more accurately depicts a man at about the age of 60. Other **portraits** of Leonardo include **Raphael's** portrait in his *School of Athens*, as well as the printed frontispiece for **Giorgio Vasari's** *Lives of the Artists*, and all portraits show Leonardo as an older man with a long, white beard. No earlier portraits are known of Leonardo, although it is thought that **Andrea del Verrocchio** could have used the young Leonardo as a model for his bronze *David* from the 1460s. *See also LUCAN PORTRAIT OF LEONARDO.*

PORTRAIT OF A MUSICIAN. This small ***Portrait of a Musician*** (c. 1485, 16 3/4 x 12 1/8 in., **Milan**, Pinacoteca Ambrosiana) is sometimes attributed to Leonardo but is more convincingly considered a work by **Giovanni Ambrogio de Predis** based on that fact that it depicts a male sitter with stiffer facial features than we typically see in Leonardo's portraiture, as well as a black background characteristic of de Predis's portraits. This **oil**-on-walnut wood panel painting could perhaps be a portrait of Italian composer Franchino Gaffurio (1451–1522), the *maestro di cappella* of the **Milan Cathedral**, who was known to be a personal friend of Leonardo, but it has also been identified as Florentine composer Atalante Migliorotti (1466–1532), who was a **music** student of Leonardo, or French composer Josquin des Prez (c. 1450–1521), who worked for the Sforza family in Ferrara and Milan in the 1480s.

The artist has painted this man in a highly realistic half-length, three-quarter profile, where the sitter looks out of the painting while holding a musical score in his right hand. Most Milanese **portraits** of the time showed the sitter in profile, so here the artist has introduced the angled view first seen in **Florence** a few decades earlier. He wears a rich black robe with a white undershirt and an orange chevron hanging down the front. Some scholars have suggested a collaboration, where Leonardo painted the face, done with soft **light** and dark contrasts, to illuminate the skin tone and texture, and he framed the face with highly detailed curls that seem to pour down toward the shoulders, while Ambrogio or another artist painted the outfit and red cap. Overpainting was removed from the panel in 1905, to reveal a sheet of music in the man's hand. Regardless of its attribution, this work is an excellent example of the realistic portraiture of the Italian **Renaissance**, which sought to show the humanity of the sitter *See also* LEONARDESCHI; PAINTINGS.

PORTRAITS. There are 10 portraits generally attributed to Leonardo, and the best-known panels are his engaging portraits of young courtly women, shown in half-length compositions either in profile or a three-quarter view. Leonardo completed four female portraits in **oil** on wood and two portraits on paper and vellum, while a ***Portrait of a Lady in Profile*** is often attributed to Leonardo's student, **Giovanni Ambrogio de Predis.** Two male portraits include the oil painting ***Portrait of a Musician***, which is also attributed to de Predis, and a drawing entitled ***Portrait of a Man in Red Chalk***, which is slightly different from the one by Leonardo's student, **Francesco Melzi**. Leonardo was one of the earliest Italian artists to use oil paint in his portraiture, and with his studies of shading and **light**, together with his careful observation of the shape and movement of the human body, he was able to achieve an unprecedentedly high level of realism in his art.

His figures in ***Ginevra de' Benci***, ***Belle Ferronnière***, and his most famous portrait, the ***Mona Lisa***, gaze out of the painting at the viewer, thereby breaking gender barriers in terms of a familiarity between the viewer and the sitter. *Ginevra de' Benci* is Leonardo's earliest extant female portrait and was done in **Florence**, while most other portraits were done in **Milan**, with the exception of the *Mona Lisa*, which depicts Lisa Gherardini, the wife of Florentine merchant Francesco del Giocondo, begun in Florence and completed in either Milan or France. The ***Lady with an Ermine*** represents Cecilia Gallerani, the favorite mistress of Duke **Lodovico Sforza**, where we see a striking image of a woman petting the small ermine that squirms in her embrace while she looks out of the painting to follow a sound that has captured her attention. Another portrait depicts Lodovico's wife, Beatrice d'Este, and another is her sister, Isabella d'Este, the Marchese of **Mantua**, done in a chalk drawing in profile. The ***Head of a Woman*** (***La Scapigliata***) is an underdrawing on wood generally attributed to Leonardo, while the most recent portrait attribution is ***Bella Principessa***, a Milanese manuscript painting on vellum confirmed by **Martin Kemp** based on fingerprint evidence. Leonardo's portraits are all half-length figures, and some are set against a black background, while others feature an imaginary landscape that stretches off into the far distance, employing an **atmospheric perspective**. His portraits are known for their striking realism and sense of humanity. *See also* DRAWINGS; LANDSCAPES; LEONARDESCHI, PAINTINGS.

PREDIS, GIOVANNI AMBROGIO DE (c. 1455–c. 1508). Giovanni Ambrogio de Predis was a Lombard artist who worked as a portrait painter in the court of **Lodovico Sforza**, Duke of **Milan**. Although he came from a family of painters, his early training is unclear, but he is known to have hosted Leonardo in his home when Leonardo first arrived in Milan in 1483, and the artists collaborated on several **paintings** for the Confraternity of the Immaculate Conception. A commission contract notes that Ambrogio, his brother Evangelista, and another artist, perhaps Francesco Napoletano or **Bernardino Luini**, painted side panels for Leonardo's ***Virgin of the Rocks*** for the confraternity's chapel at San Francesco Grande in Milan. These panels, now separated from the central scene and located in the National Gallery in London, depict standing angels playing musical instruments.

De Predis's half-length **portraits**, in either profile or three-quarter view, are similar in style to Leonardo's portraits, except that while Leonardo usually created an imaginary landscape background done in **atmospheric perspective**, Ambrogio placed his figures in front of a **monochromatic** black background. Leonardo's ***Portrait of a Musician*** has also been convincingly attributed to de Predis, as has Leonardo's ***Portrait of a Lady in Profile***, which could be a collaborative work between Leonardo and his student. *See also* LEONARDESCHI.

R

RAPHAEL (1483–1520). Raffaello Sanzio, known as Raphael, was a High **Renaissance** painter who worked primarily in **Florence** and **Rome.** He, Leonardo, and his contemporary, **Michelangelo**, are the three best-known artists who advanced art style from the Early Renaissance. Raphael, in particular, is known for his restrained, idealized figures, which incorporate ideas from classical antiquity. Raphael was born in Urbino, and his father, Giovanni Sanzio (c. 1435–1494), was a painter and poet in the court of Duke Federico da Montefeltro (1422–1482), for whom he wrote a discourse on painting and listed the top 27 artists of the day, one of whom was Leonardo. Santi continued working for Guidobaldo da Montefeltro (1472–1508) until his death, when Raphael was 11 years old. Soon thereafter, the young orphaned artist began work in the studio of Pietro Perugino (c. 1446–1523), a well-known Early Renaissance painter working in the nearby hill towns of Perugia and Florence. Raphael then started work as an independent master by 1500 and for the next three years, he was busy with religious commissions for many small churches in the surrounding area, as well as work in the Piccolomini Library in Siena.

In 1504, Raphael established his workshop in Florence, where his style moved away from that of Perugino's toward a new approach heavily influenced by Leonardo's voluminous figures turning in space, set in soft lighting against a landscape background. **Giorgio Vasari** was the first to notice the older Leonardo's influence on this young artist, 30 years his junior. Perhaps Raphael studied in Leonardo's workshop during this time. Leonardo had already completed a number of Madonna and Child paintings in Florence early in his career, and when he returned in 1500, he began work on the ***Battle of Anghiari*** and the ***Mona Lisa***. Raphael's sketch entitled *Young Woman on a Balcony*, a pen-and-ink drawing from c. 1504 (Paris, Louvre Museum) resembles the *Mona Lisa* in pose, appearance, and setting, which Raphael repeated in his *Lady with a Unicorn*, from c. 1505 (Rome, Borghese Gallery). These **portraits** show a three-quarter view seated female flanked by balcony columns, a new format introduced by Leonardo that creates a solid pyramid composition. Raphael's *Madonna of the Meadow* (c. 1506, 44 x 35 in., oil on wood, Vienna Kunsthistorisches Museum) also reveals a pyramidal composition. Here, he depicts the Virgin seated on the ground against a softly modeled landscape background with slate blue hills that rise up in the distance. She supports a chubby infant Christ, who walks in front of her toward his infant cousin, John the Baptist, and together they grip the staff of a long cross.

This composition is adapted from Leonardo's Virgin and Child with the infant Baptist **paintings**, while Raphael abandoned his crisply delineated Perugínesque figures for the shading and **color** gradations seen in Leonardo's work. While in Florence, Raphael also made many sketches of dynamic figures, perhaps inspired by the battle scenes by Leonardo and Michelangelo, where he drew men in battle twisting and turning in space, inspiring some of the

figures in his later Vatican **frescoes**. Raphael also sketched Leonardo's lost ***Leda and the Swan*** and used a similar contrapposto pose in his *Saint Catherine of Alexandria*. These **drawings** provide valuable information about some of Leonardo's lost works, including a possible second version of his *Mona Lisa*, which could be represented in Raphael's drawing of a lady seated in front of a balcony.

In late 1508, Raphael transferred his large workshop to Rome at the invitation of Pope Julius II, who might have known of Raphael through his architect, **Donato Bramante**, a distant relative of Raphael. Raphael began work on the Vatican apartment frescoes while Michelangelo painted the Sistine ceiling, and Raphael continued his suite of rooms for **Medici** pope **Leo X**, elected in 1513, after the death of Julius. That same year, Leonardo moved to Rome at the invitation of the Medici, working as an engineer and architectural advisor. This rich artistic culture, where all three artists worked in proximity to one another during the first two decades of the 1500s, is credited with initiating the High Renaissance. *See also* BOTTICELLI, SANDRO; CASTAGNO, ANDREA DEL; MASACCIO, POLLAIUOLO, ANTONIO DEL; UCCELLO, PAOLO.

RENAISSANCE. The Roman Empire gradually fell after Visigothic King Alaric I sacked **Rome** in 410, and the Italic Peninsula came to be divided into regions governed by aristocratic feudal lords, the papacy, and the Holy Roman Emperor. By the 11th century, however, powerful city-states had begun to grow out of these small, agrarian communities, modeled, in part, on ancient Roman political ideals. During the next few centuries, an emerging merchant class consolidated power within these city-states through highly prosperous trade and banking industries, and these merchants challenged the traditional power base. Medieval lords maintained fortified castles scattered throughout the countryside, but now they had urban competitors for authority. Those who sought alliance with the Holy Roman Emperor were called Ghibellines, while the merchant and papal allies were called Guelfs. While these two factions vied for power through the 1300s, the Bubonic Plague, or "Black Death," struck in the 1340s and presented new opportunities for social advancement among the survivors. People began to consider what it meant to be human and think about where they fit within the dramatic societal changes that characterized this era.

The medieval era was followed by a time period traditionally called the Renaissance, a term first used in the mid-1800s to describe the "rebirth" of **classicism**, which had begun in the 1300s, called the Proto-Renaissance, through the 1400s, called the Early Renaissance, and into the first half of the 1500s, which is called the High Renaissance and Mannerism. Although our understanding of the Renaissance is focused on the idea that politics, philosophy, art, and science were largely influenced by classical Greek and Roman cultures, scholars have expanded these observations to include the influence of trade and conquest, new scientific discoveries, new political structures and religious ideology, and a new geopolitical and socioeconomic context anticipating the modern age. This broad cultural context set the stage for the emergence of naturalism in art, which is what best characterizes the art of Leonardo.

During the Renaissance, a new merchant class consolidated power within the major city-states through highly prosperous trade and banking industries, thereby challenging the traditional aristocratic power base. Medieval lords, for example, the Sforza of **Milan**, maintained fortified castles scattered throughout the countryside, but now they had urban, merchant competitors, notably the **Medici** of **Florence**. Furthermore, expanded trade routes linked the major cities of Europe with Asia, Africa, and the Americas, and this rich cultural exchange brought vast scientific, technical, and mathematical advances to Europe that transformed the way people understood the world. The material goods that arrived in Europe also contributed to an increase in prosperity, which gave people the economic means to consciously seek ways to advance their cultural legacy.

The way we understand Renaissance art today is shaped by the writings of **Giorgio**

Vasari, whose collection of artist biographies, called *Lives of the Most Excellent Painters, Sculptors, and Architects*, was first published in 1550, and favored Florentine artists from his own era. His ideas were followed by Jacob Burckhardt's (1818–1897) *The Civilization of the Renaissance in Italy*, from 1860, which gave the Renaissance era a primacy in art historical methodology and explains its continued popularity today. Some art historians now debate the legitimacy of this focus on the Renaissance, especially given the increased study of global art, which has enriched our understanding of the discipline. Yet, the Renaissance remains one of the most thoroughly documented eras in art history, making it useful to examine in detail within our ever-expanding art historical canon. *See also* CATHOLICISM; HUMANISM; MANTUA; MATHEMATICS; VENICE

REVOLVING BRIDGE. *See* INVENTIONS.

RICHTER, IRMA ANNE (1876–1956). The daughter of art dealer and Leonardo scholar **Jean Paul Richter** and art historian Louise Schwaab Richter, Irma studied art at the Slade School of Art in London and then at Oxford and in Paris. Her sister, Gisela Richter, became the first female curator of Greek and Roman art at the Metropolitan Museum of Art, while Irma continued her father's work on Leonardo. In 1952, Irma published an abridged version of her father's two-volume study on Leonardo's **notebooks**, where she organized his writings under the general headings of "True Science," "The Universe," "Flight," "The Arts," and so on. In this way, Irma focused on Leonardo's foundational approach to observing the physical world before moving to a more balanced examination of both Leonardo's scientific and artistic studies. *See also* BODE, WILHELM VON; FREY, KARL OTTO; LIPHART, KARL EDUARD VON; MCCURDY, EDWARD ALEXANDER COLES; MORELLI, GIOVANNI; MUSEUMS; WAAGEN, GUSTAV FRIEDRICH.

RICHTER, JEAN PAUL (1847–1937). Jean Paul Richter was the first modern art historian to recognize the educational value of Leonardo's vast collection of **notebooks** and **drawings**, which had not been studied since the mid 1600s, and systematically organize and classify the subjects of Leonardo's diverse drawings. Born in Dresden, Richter studied theology and was hired as a tutor for the German noble Hesse family, where he had the opportunity to travel throughout Europe and gain an appreciation for art. He was eventually hired to write passages for the Baedeker travel guidebook on Italy, the first of which was published in 1866.

In 1876, Richter met art connoisseur **Giovanni Morelli** in Italy and learned Morelli's scientific method of examining the minor details of a work of art to establish attributions, and in 1883, Richter published *The Literary Works of Leonardo da Vinci*, which was reissued in the early 20th century. Here, Richter combed through both published and unpublished notebooks, transcribed Leonardo's text, and highlighted a selection of writings that span Leonardo's career and interests. Richter acknowledged that despite his translations, much of Leonardo's writings remained a mystery because Leonardo not only wrote from right to left, but also ran words together and did not use punctuation. Many phrases are also illegible.

Richter began with Leonardo's discussion on painting and his *paragone* on the superiority of painting over **sculpture**, and then he included sections on geography, **astronomy**, and other disciplines. This introductory study laid the foundation for further research on Leonardo's notebooks done by **Edward Alexander Coles McCurdy**, who included more of Leonardo's scientific studies in his publication, and Richter's daughter, **Irma Richter**, who established a new classification system for Leonardo's writings that highlighted his conceptual approach to the physical world rather than the division of his ideas into different disciplines. *See also* BODE, WILHELM VON; FREY, KARL OTTO; LEFT-HANDED; LIPHART, KARL EDUARD VON; PAINTINGS; WAAGEN, GUSTAV FRIEDRICH.

ROBOT (ROBOTIC KNIGHT). *See* AUTOMATON, INVENTIONS.

ROME. Once the papacy returned to Rome from Avignon in the early 1400s during the papacy of Martin V and Europe had recovered from the mid-1300s outbreak of the plague, city officials began a lengthy plan to revitalize this once-important city. By the late Middle Ages, Rome was a small city with dirt roads and open areas used to graze animals, while ancient buildings were left to crumble into ruins. At the height of the ancient Roman Empire, the city had about 1 million inhabitants, but by the early 1400s, about 25,000 people lived in Rome. By the 1500s, Rome was the center of the Papal States and held great power throughout Europe. This growth was initiated in 1447, by Pope Nicholas V, who was elected with the financial support in **Florence** of Cosimo de' **Medici**, who became the papal banker. Pope Nicholas founded the Vatican Library, which was enriched with manuscripts from the Fall of Constantinople in 1453, and Nicholas hired **Leon Battista Alberti** to oversee numerous architectural restoration projects; in the 1470s, Pope Sixtus IV oversaw the construction of the Sistine Chapel and expanded the infrastructure of the city with paved roads, squares, fortifications, and fountains that brought more water into the city.

By the early 1500s, Pope Julius II, who ruled from 1503 until his death in 1513, had initiated the most ambitious building project in Rome, the rebuilding of the Basilica of Saint Peter's, begun by **Donato Bramante.** He also hired **Michelangelo** to design his freestanding funerary monument and paint the Sistine Ceiling, while **Raphael** painted the walls of the Papal Apartments next door. His successor, Medici pope **Leo X**, was the second son of Lorenzo de' Medici, and he continued these Roman projects until his death in 1521.

In 1513, Leonardo was invited to Rome by Giuliano de' Medici, the brother of the newly elected pope, Leo X, who was Giovanni di Lorenzo, the second son of Lorenzo de' Medici. There he was given an apartment in the Palazzo Belvedere where he lived with his students, **Salaì** and **Francesco Melzi**. Leonardo spent three years in Rome, where he worked to improve the city infrastructure with studies of **hydraulics** and architectural plans. In 1515, Giuliano de' Medici hired Leonardo to design a plan to drain the swampland around Terracina, called the Pontine Marshes, to reduce the rate of malaria in the region. Leonardo designed several canals from the Ufente River called the Canale Giuliano and Canale Portatore. When Giuliano died in 1515, the project was stopped by the local citizens who saw this as a papal attempt to take over their fishing rights. Later, Pope Sixtus V died of malaria after visiting the marshes.

While in Rome, Leonardo also tried to create a solar reflector in the shape of a round, parabolic disk that could amplify the heating process of water to dye fabrics more quickly. This invention, never realized, would have benefited the Medici family dye industry. Leonardo continued his experimentation with mirrors, and it was in Rome where he perhaps drew ***Portrait of a Man in Red Chalk***, which would have required him to use a mirror to show his face at an angle. Nevertheless, **Giorgio Vasari** mentioned that Leonardo did not have any viable commissions there, however, and was bored in Rome. His **notebooks** reveal **drawings** of water and weather patterns, with deluges and storms, and he completed his last painting, ***Saint John the Baptist***, in Rome.

In 1515, Leonardo was sent to Bologna as a diplomatic advisor to Pope Leo X, and there he likely met the newly crowned king, **Francis I** of France, while a peace agreement was negotiated. Documents describe a peace offering Leonardo made for the king that consisted of a mechanical lion (***Madrid Codices*** I, fols. 90v and 91r) that walked several steps and then a door would open in his chest to show the French fleur-de-lis. Soon thereafter, Leonardo was invited to France, and he likely went there with the approval of Leo X, who was cultivating a political alliance with the French. At this point in Leonardo's career, his role as a political liaison perhaps overshadowed his artistic influence in Italy. *See also* ARCHITECTURE; AUTOMATON; ENGINEERING; INVENTIONS; *PARIS MANUSCRIPTS*.

ROMORANTIN. Romorantin is a medieval town in the Loire Valley along the Sauldre

River in north-central France near the royal châteaux of Blois and Chambord. The Sologne region has game filled forests, ponds, and rivers, and a sandy clay soil content conducive to the cultivation of tart grapes for wine. The Romorantin grape is a white grape that has been cultivated in the region since the **Renaissance**, and this industry was one of the many reasons for King **Francis I's** interest in the area. In 1517, Francis I hired Leonardo, his first painter, engineer, and architect, to design an **ideal city** plan, which exists today in several ambitious **drawings** located in the British Library in London (primarily folios 270–71), featuring waterways with an automatic cleaning mechanism fueled by mills, canals linked to the Cher River for transportation, and a large royal palace along the banks of the river that was intended as the new royal capital.

Francesco Melzi worked with surveyors to measure existing streets and buildings similar to Leonardo's method for mapping the Italian town of Imola, and Leonardo had previously theorized an ideal city plan for **Lodovico Sforza** in **Milan**. Although never built, Leonardo's plans to organize and expand Romorantin into an ideal royal city remains important to the history of urban planning. Here, Leonardo sought to combine practical infrastructura needs and artistic beauty to promote both health and happiness. The specifics of Leonardo's plan involved raising the river, changing its direction, and moving a large population to prefabricated housing from nearby Villefranche. The new royal residence incorporated an older, ancestral home on the site with a new palace and extensive gardens located on either side of the Saudre River. The twin palaces were to have canals around them that fed water to fountains in every town piazza. Windmills and watermills were to be located along the river, while streets were to be paved. Upon Leonardo's death in 1519, land had been leveled for the palace and a 10-foot-tall portion of the walls built before Francis I abandoned the project and shifted his attention to the royal Château du Chambord, where a helix-spiral stairway, perhaps designed by Leonardo for Romorantin, was built. *See also* ARCHITECTURE; ENGINEERING, INVENTIONS, WATER STUDIES.

S

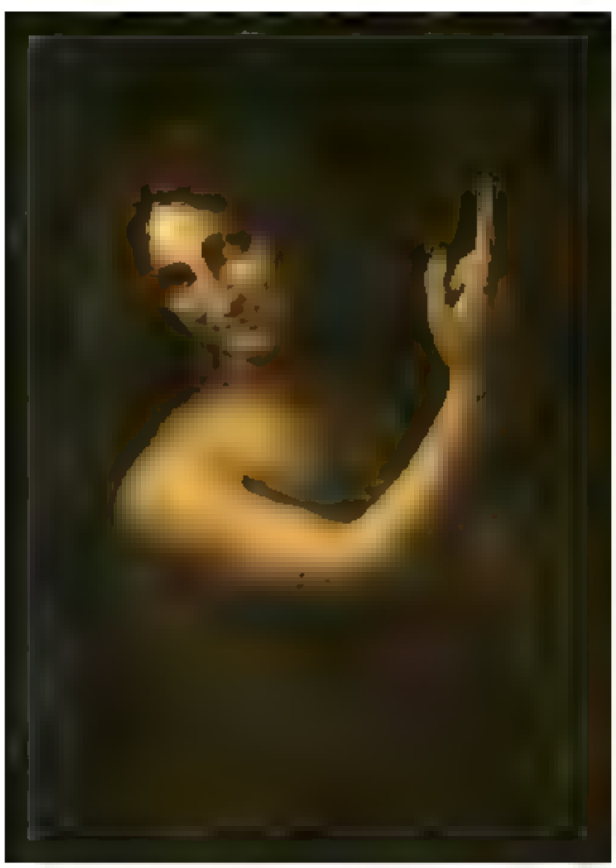
SAINT JEROME IN THE WILDERNESS. *Saint Jerome in the Wilderness* is an unfinished **tempera** and **oil** on walnut panel painting that Leonardo worked on during the 1480s (41 x 30 in., **Rome**, Vatican Museums). Firmly attributed to Leonardo, this work nonetheless has an incomplete provenance but is thought to have been found disassembled in Rome by Cardinal Joseph Fesch, the uncle of Napoleon Bonaparte, who was a French diplomat in Rome and an important art collector. Upon his death, his heirs sold the painting to Pope Pius IX, who placed it in the Vatican Museum. Less is known about this work, perhaps because it is incomplete, but it nonetheless reveals important information about Leonardo's artistic process. The painting depicts the penitential Saint Jerome in the Syrian Desert, a subject made popular in the **Renaissance** by many Northern Italian artists, including Lorenzo Lotto, **Andrea Mantegna**, and **Giovanni Bellini**, as well as such Northern European artists as Lucas Cranach and **Albrecht Dürer**, who were interested in the solitary, contemplative figure set in a vast landscape background.

Leonardo's image shows a thin, elderly man seated on a rock against a rocky landscape background. Saint Jerome wandered the Syrian Desert as a hermit saint, denying himself food and worldly luxuries. He tilts his head to gaze at a cross, while his attribute, a lion he befriend in the desert after pulling a thorn from its paw, appears in the foreground of the painting. Leonardo's interest in **anatomy** originated during his apprenticeship with **Andrea del Verrocchio**, whose *Baptism of Christ* (c. 1475, **Florence**, Uffizi Gallery) reveals a similar, although less anatomically accurate, emphasis on the bones and muscles of the human torso. Saint Jerome has clearly defined collarbones, neck tendons, and arm muscles, which reflect a lifetime of careful observation of the human body. His anatomical details are perhaps exaggerated to emphasize the emaciated form of a man who suffers for his religious beliefs, while beating his chest with a rock held in his right hand. The unfinished work shows the underpainting on the panel, where Leonardo sketched out the forms and then began to layer on the darker pigments, building up to the center of the work, where the three-dimensional forms would begin to be revealed through the layering of lighter pigments. *See also* LANDSCAPES; MUSEUMS, PAINTINGS.

SAINT JOHN THE BAPTIST. Leonardo's *Saint John the Baptist* is a securely attributed painting of the Baptist, shown in a half-length portrait wearing a fur shirt draped over one shoulder while smiling at the viewer and pointing upward. His head, framed by long, wavy hair, tilts toward his right shoulder. His left hand clutches a reed cross against his chest. The Baptist's flesh is modeled in a deep **chiaroscuro** that blends into a dark, **monochromatic** background, and the intimacy of the work gives a sense of immediacy. Done in oil-on-walnut panel, the painting measures 27 x 22.5 inches and is located in the Louvre Museum in Paris. This work is thought to be Leonardo's last painting, commissioned while in **Milan**, begun in about 1513, and completed in

Rome. In 1516, it was taken to France, where it was mentioned in Leonardo's workshop at **Clos Lucé** by Antonio de Beatis, who wrote a journal while traveling throughout Europe in the entourage of Cardinal Luigi of Aragon in 1517–1518.

After Leonardo's death, the painting entered the collection of King **Francis I** at Fontainebleau but was traded and sold several times before returning to France in 1661, where it was placed in the Louvre. In the **Renaissance**, John the Baptist was traditionally shown either baptizing Christ or as Christ's childhood friend. He is typically the intercessory figure who draws the viewer into the painting through gaze and gesture, and here he points upward to remind the viewer of salvation through baptism. Often shown gaunt and impoverished from his desert sojourn, here Leonardo reveals a sensual figure with soft, glowing skin and a round, alluring face. This new format of a youthful Baptist set against a dark landscape was depicted by **Raphael** in 1518 (**Florence**, Uffizi Gallery), among other Florentine artists, as well as the numerous versions made by Leonardo's students and followers, including **Salaì**, **Giampietrino**, and **Bernardino Luini**. A drawing of an angel found in Leonardo's notebook, with a notation that the drawing was done by Salai, called the *Angelo Incarnato*, also in the Louvre Museum, shows a similarly posed nude male figure with an exposed phallus gazing at the viewer while pointing to the heavens. Salai's Baptist captures the same eroticism, while Giampietrino's version reveals a fully clothed Baptist humbly gazing downward. *See also* CATHOLICISM; LEONARDESCHI; PAINTINGS.



Leonardo da Vinci, *Saint John the Baptist*, 1513–6, oil on walnut panel, 27 x 22.5 inches, Paris, Louvre Museum.

SALA DELLE ASSE. In 1494, **Lodovico Sforza** became the duke of **Milan** and moved into the family castle, the Castello Sforzesco, in Milan. There, he hired many artists to renovate the castle to transform it from a feudal-era residence into a princely palace. During this time, Leonardo was working on the ***Last Supper***, and in 1498, the duke commissioned Leonardo to paint the walls and ceiling of a corner tower room with a garden scene, which was completed by Leonardo and his assistants. The upper walls of the room show either 16 or 18 mulberry or willow tree trunks with branches that grow up into the curved ceiling to create the appearance of a canopy with tree limbs decoratively looped together with golden ribbons. Two windows illuminate the room. Today, the lower wall is covered with wood panels similar to those during the **Renaissance**, which help protect the deteriorating plaster, while the ceiling reveals a darkened silhouette of the original mural. Recent restorations have revealed more of Leonardo's work on the lower walls of the room, which had been covered with as many as 17 layers of whitewash throughout the years. *See also* FRESCO, LANDSCAPES; PAINTINGS.

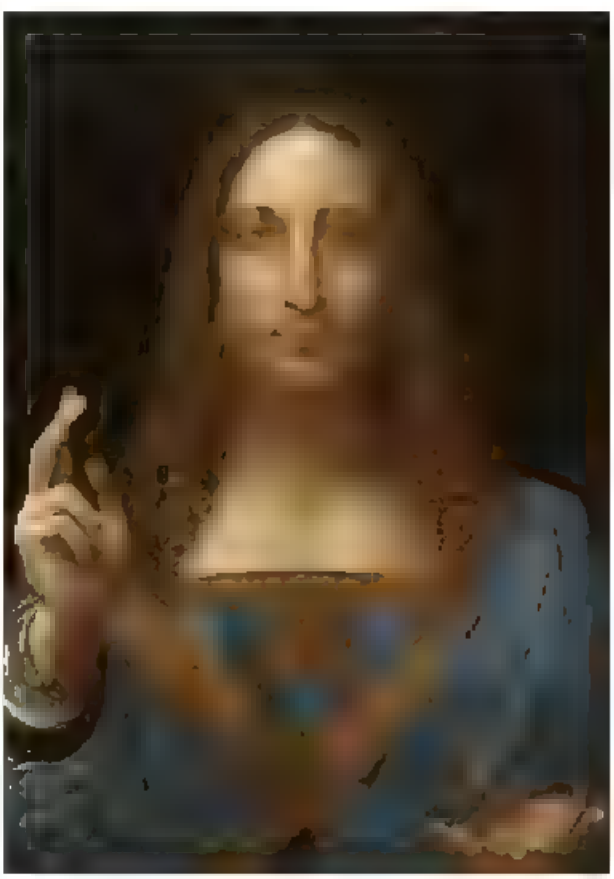
SALAÌ (1480–1524). One of Leonardo's students, Gian Giacomo Caprotti da Oreno was nicknamed "Salai," or the "little devil," because he was known to steal from Leonardo,

lie, and eat all of his food. Salai's father worked at Leonardo's vineyard, located at Porta Vercelina, just outside **Milan**, and Salai entered Leonardo's workshop as a servant and student at the age of 10, and remained there 25 years, until 1518, when he left France to return to Leonardo's vineyard outside Milan. Leonardo wrote in his diary on 22 July 1490, that when Salai entered his household, Leonardo set aside money for some new clothing for him, but Salai stole the money, and then at dinner the next day, Salai ate enough food for two people and broke three containers and spilled the wine.

When Leonardo died in 1519, Salai inherited half the vineyard, and in 1523, he married Bianca Coldiroli d'Annono, before dying a year later in a duel. During this time, Salai, who called himself Andrea Salai, trained as a competent artist and painted a nude version of the ***Mona Lisa*** called the *Mona Vanna* (Paris, Louvre Museum). He is also credited with painting copies of many of Leonardo's works, notably a *Mona Lisa* in the Prado Museum. **Giorgio Vasari** described Salai as a curly haired beauty, and it is thought that Leonardo used Salai as a model for several of his **paintings**, for example, the ***Bacchus***. Leonardo's drawing *Angelo Incarnato* depicts a nude male figure thought to be Salai.

Salai entered Leonardo's studio during Leonardo's first stay in Milan, in about 1490, and when Leonardo returned to Milan in 1506–1513, he accepted **Francesco Melzi** into his studio. While Salai was from humble origins, Melzi was of minor nobility. Thus, when both students traveled with Leonardo, Salai worked as a servant with a lower pay, while Melzi became Leonardo's main assistant and secretary, responsible for organizing Leonardo's **notebooks** for publication. Salai inherited some of Leonardo's paintings, perhaps including the *Mona Lisa*, which he is thought to have sold to **Francis I**. *See also* BOLTRAFFIO, GIOVANNI ANTONIO; HOMOSEXUALITY; LEO X; LEONARDESCHI, *MADONNA OF THE YARNWINDER* (*LANSDOWNE*); ROME.

SALVATOR MUNDI. The *Salvator Mundi* is an **oil**-on-walnut panel painting dated c. 1500 (25.8 x 19.2 in.) recently purchased for display in a museum in Abu Dhabi newly opened in partnership with the Louvre Museum in Paris, called the Louvre Abu Dhabi. Although the perceived corporatization of the Louvre Museum has been controversial, the desire to solidify an east–west artistic dialogue is at the center of this collaboration. The centerpiece of the new museum collection is the *Salvator Mundi*, purchased from Christie's at an art auction in New York for the record sum of $450.3 million, which includes a commission, the most ever paid for a painting. Since fewer than 20 **paintings** are attributed to Leonardo, despite his fame as one of the best-known artists in history, the discovery of a new Leonardo painting on the art market is exceedingly rare. This fact, together with a large budget provided for the establishment of a new art collection in the United Arab Emirates, fueled interest in this painting despite its disputed attribution and damage caused by overpainting and overcleaning.



Attributed to Leonardo da Vinci, *Salvator Mundi*, c. 1500, oil on walnut panel, 25.8 x 19.2 inches, Abu Dhabi, Louvre

Other artists painted this subject, one of whom was **Joos van Cleve**, credited with bringing Leonardo's style to Antwerp. His *Salvator Mundi* (c. 1516–1518, Paris, Louvre Museum) depicts the same composition set against a gold background, where Christ's orb is an impressive glass globe that reveals the Earth inside, while reflecting the **light** of a window distorted by the curve of the glass. The work attributed to Leonardo, instead, shows a transparent orb with Christ's hand beneath, with his blue robe appearing through the glass. Other early examples are primarily Flemish and include versions by Gerard David and Quentin Metsys, while the subject is also found later in Italy. *See also* BOLTRAFFIO, GIOVANNI ANTONIO; LEONARDESCHI; MUSEUMS.

SAN BERNARDO ALTARPIECE. On 10 January 1478, Leonardo received his first independent commission for an altarpiece of either the *Nativity* or the *Vision of Saint Bernardo* for the Chapel of San Bernardo in the Palazzo Vecchio in **Florence**. He had just left the workshop of **Andrea del Verrocchio** in 1477. He hired an assistant to begin work on the cartoon, but five years later the work had not progressed and the commission was given to **Domenico Ghirlandaio**. Ghirlandaio also never finished the commission, and so it was transferred to Filippino Lippi (1457–1504), who completed the altarpiece in 1485, now called the *Enthroned Madonna and Saints*, located in the Uffizi Gallery in Florence. The **Anonimo Gaddiano** mentioned that Lippi used Leonardo's cartoon, but this is unlikely given that the finished painting depicts a different subject. Lippi could have used some of Leonardo's preliminary sketches, however, although none of those are known. *See also* CATHOLICISM; PAINTINGS.

SANGALLO, GIULIANO DA (c. 1445–1516). The work of Florentine architect Giuliano da Sangallo was tremendously influential on Leonardo given that the two artists were similar in age and both worked for the **Medici** in **Florence** and later on in **Rome**; therefore, their careers crossed paths many times throughout their lives. Sangallo was born in Florence, and his father's architectural work for Cosimo de' Medici paved the way for Sangallo to secure the patronage of Lorenzo de' Medici early in his career. His brother, Antonio da Sangallo the Elder (c. 1453–1534), also became an important **Renaissance** architect, as were several other younger relatives. Sangallo was born when **Filippo Brunelleschi's** Florence Cathedral dome was just being finished, and as a young man he likely witnessed the completion of the lantern project, as did Leonardo. He also studied **Vitruvius**, whose ancient Roman treatise on **architecture** had just been rediscovered and made available through translations and printed copies.

Sangallo's earliest architectural projects were for fortifications, and these studies were also of central interest to Leonardo, who introduced himself as a military engineer when first meeting his patron, **Lodovico Sforza**. In 1485, Sangallo was commissioned to build the Medici Villa at Poggio a Caiano outside Florence, which he based on **Leon Battista Alberti's** villa descriptions found in his treatise on architecture from about 1450. In 1486, Sangallo began construction on the centrally planned church of Santa Maria delle Carceri in Prato, just north of Florence, which was commissioned by the Medici. This small church commemorated the spot of a local miracle and was designed with a Greek cross plan of four equal sides and a high altar in the crossing, beneath the central dome. This church plan, symmetrical on all four sides, was widely considered an ideal design superior to the basilica church plan, and Leonardo made numerous sketches of centralized churches throughout his life. This church type was rarely built, however, because of its smaller format, which could not accommodate as many people.

In 1500, just after Leonardo returned to Florence from **Milan**, the two architects were hired to provide advice on the foundations of the Church of San Salvatore, which were beginning to be unstable. Some scholars think Sangallo, who also worked in bronze, also provided advice to Leonardo on how to cast his colossal bronze Sforza equestrian, which by now would have been on hold with the French invasion of Milan. *See also* BRAMANTE,

DONATO; FILARETE, ANTONIO DI PIETRO AVERLINO; MARTINI, FRANCESCO DI GIORIGO, SCULPTURE.

SAVONAROLA, GIROLAMO (1452–1498). Girolamo Savonarola was a Dominican preacher in **Florence** whose father was a wealthy physician and scholar. He received a university degree in his hometown from University of Ferrara but abandoned his medical studies to join the Church. From a young age, Savonarola was concerned with what he considered a corrupted state of the Church and the world in general, and he wrote apocalyptic poetry early in his life. He eventually decided to join an ascetic branch of the Church that focused on avoiding the temptations of the physical world that lead to sin.

Savonarola first traveled to Bologna, where he joined the Convent of San Domenico, took a vow of poverty, and studied theology, as well as classical philosophy, before angering members of the school, who sent him back to Ferrara to work with the novices before being reassigned as a lecturer in the Convent of San Marco in **Florence**. There, he lectured widely, and although his speeches initially were not very popular due to his inelegant rhetorical style and strict asceticism, disavowing all forms of property ownership, he gradually developed a group of adherents. In 1490, he was befriended by humanist **Giovanni Pico della Mirandola**, who was in trouble with the Church for his mystical views and adherence to magic, and with the help of Lorenzo de' **Medici**, Pico's benefactor, Savonarola was invited back to San Marco in Florence. His prophecies became even more dramatic, with sermons against the rich, tyranny, and the corrupt clergy, and although they were at first ignored, the death of both Lorenzo de' Medici and Pope Innocent VIII in 1492, and the French invasion of Italy in 1493, seemed to affirm his warnings.

As the French Army advanced toward Florence, the now-powerful Savonarola orchestrated the exile of Piero de' Medici, while negotiating protection for the city. The French Army bypassed Florence, after which Savonarola called for penitence, while helping to build a new government where power was shared among a broader class of skilled laborers to form a Great Council of 500 governing members. Savonarola's new power was soon contested by the papacy; however, concerned with the socioeconomic upheaval he promoted, he was excommunicated in 1497, and hanged in the Piazza della Signoria in 1498. In 1502, **Piero Soderini** was elected gonfalonier of the Republic of Florence. Savonarola's influence rose while Leonardo worked in **Milan**, but his frequent trips back to Florence kept him connected to the political changes that were occurring in his home city. When he returned to Florence in 1500, he was hired by Soderini to paint a fresco of the ***Battle of Anghiari*** on the walls of the Great Council Chamber in the Palazzo della Signoria, a commission he never completed. *See also* BOTTICELLI, SANDRO; CATHOLICISM; HUMANISM, PAINTINGS.

SCUBA GEAR. *See* DIVING SUIT, INVENTIONS.

SCULPTURE. Leonardo's sculptural career was focused on designing large bronze equestrian monuments, none of which were realized during his lifetime. In Leonardo's ***Codex Atlanticus***, he recorded a visit to Pavia in June 1490. There, he saw the *Regisole*, a bronze equestrian monument from antiquity. Leonardo already knew **Donatello's** bronze equestrian of Erasmo da Narni, erected in the Piazza del Santo in Padua in 1453, as well as **Andrea del Verrocchio's** bronze equestrian of Bartolomeo Colleoni in **Venice**, completed just after his death in 1488. In Pavia, Leonardo sketched the *Regisole* and noted that the imitation of ancient works is superior to modern works. His own horse studies were inspired by this example, which he hoped to surpass in scale and technique.

Leonardo's first large horse, called the *Gran Cavallo*, or *Colossus*, was commissioned by Duke **Lodovico Sforza** in 1482, to commemorate his father, Francesco Sforza, and was to be the largest bronze horse in the world, measuring 56 feet tall and weighing 80 tons. It required 100 tons of bronze, which was to be cast in a single piece. Leonardo made many sketches of the horse (in the ***Madrid Codices***) and completed a scale clay model that was displayed in

the courtyard of the old Sforza Palace in **Milan** before being destroyed during the French invasion of 1499. The horse was originally meant to rear up on its hind legs, but Leonardo altered the design to a horse striding forward. He then made numerous sketches of a series of large furnaces needed to cast the bronze and even a crate for moving the massive clay model.

Plans to purchase the bronze never came to fruition, as the bronze was needed to make **cannons** for the upcoming war with the French; therefore, the horse remained incomplete for 500 years, when in 1999, a bronze horse made to Leonardo's design and scale was completed by animal sculptor Nina Akamu (b. 1955) and unveiled in Milan in 1999, while the Da Vinci Science Center, in Allentown, Pennsylvania, bought the original 24-foot-tall model. A second bronze horse of the same colossal scale was cast from the model, commissioned by Frederik Meijer that same year, and is located in Grand Rapids, Michigan. Several smaller versions have been cast since then. The monument is a hollow-cast bronze, done in a technique called the "lost-wax" technique, invented in antiquity and made popular in the **Renaissance**. This sophisticated method allowed for the thickness of the bronze to be moderated so it could either be thicker and carry more weight or thinner to reduce the weight of the sculpture. For example, the huge size of the horse required more weight in the two thick legs that touch the ground, while thinner bronze was used in the two legs that lift off the ground. The bronze cast is also thinner in the upper part of the horse to make the material lighter. With these highly technical designs, the weight of the bronze was carefully controlled and balanced during the hollow casting.

In the final version, the horse lacks its planned rider, Francesco Sforza, and was cast in 60 pieces rather than the one piece that Leonardo planned. Another 24-foot-tall horse designed by Leonardo, called the Sforza Horse, was recreated out of steel and six pieces of fiberglass in **Florence** in 2007, and has been disassembled and shown at various **museums** in Europe and the United States.

The second horse monument planned by Leonardo is the Trivulzio Monument, which he worked on from 1506–1511. This commission was given to Leonardo in 1499, by Gian Giacomo Trivulzio, the mercenary soldier who led the French Army into Milan. Trivulzio later became governor of Milan and planned an equestrian sculpture to stand at his funerary chapel in San Nazaro Maggiore. Leonardo made several **drawings**, taking his Sforza sculpture as a starting point, and drew the equestrian on what was to be a marble base of eight columns and sculpted figures. A few quick sketches remain of this unrealized monument, together with a well-defined drawing in the Royal Collection Trust in the United Kingdom (pen-and-ink sheet, RCIN 912355).

A small (10 inches tall) wax horse and rider sculpture was attributed to Leonardo by **Carlo Pedretti** in the 1970s and is currently located in a private collection in London. This is thought to be the model made for an equestrian sculpture commissioned in 1506, by **Charles II d'Amboise**, the French governor of Milan after the Sforza family was overthrown. Once the governor died in 1511, the project was abandoned. In 1985, a latex mold was made of the *maquette*, and in 2012, a bronze sculpture was made and has been exhibited widely. This work shows a much more dynamic composition than the famous Bartolomeo Colleoni equestrian made by Leonardo's teacher, **Andrea del Verrocchio**, in 1480–1488, in Venice. While the mercenary soldier on Colleoni's horse strides forward forcefully, lifting one leg off the ground, Leonardo's design was for a horse running forward and kicking both back legs off the ground. The rider leans back to shift the center of gravity in a sophisticated composition needed to balance the weight of the bronze with gravity. This dynamic composition is possible in a small scale sculpture, but it has never been attempted in a larger format.

Many drawings show more horse compositions, some with the two front legs rearing up, as found in the red chalk and pen drawing of a rearing horse in the Royal Collection in London (RCIN 912336). Leonardo's rearing horse and mounted rider drawing was made for the ***Battle of Anghiari*** mural, which was never completed, and throughout his life, Leonardo made many horse sketches as part

of his **animal studies**. He studied the **anatomy** of the horse and even considered writing a treatise on it. **Giorgio Vasari** mentions that Leonardo worked in sculpture while in the studio of Verrocchio, modeling clay heads in his youth. Another study, in the *Madrid Codices*, shows a drawing of the armature for an outer mold for a colossal bronze horse neck and head. In the *Madrid Codex* II, folios 141 through 157 include a section on the "Great Horse of Milan," which is the equestrian for Francesco Sforza. Leonardo's work on this colossal horse spanned more than 10 years and ended when Lodovico Sforza used the bronze allocated for the monument to make cannons for battle against the French. What we know of the project remains in Leonardo's **notebooks**, where he sought solutions for this type of monument the scale of which had never been done before.

By May 1491, Leonardo had completed a scale clay model, unveiled at a Sforza marriage festival in 1493, but a year later, in 1494, the bronze was used for cannons. Leonardo's drawings first focus on the pose and movement of the horse, and then he moved to the logistics of the mold, designed first with the horse on its side, and then upside down, where he drew such details as the bolts needed for the outer cast. Then, he decided not to follow the traditional lost-wax technique but instead designed a method where an outer double-shell mold was to be built over the clay model, then a wax model made, and then the double-shell mold recast, strengthened, and refitted to reduce imperfections. A series of tubes were used for the molten bronze, so it could be poured from different parts of the sculpture simultaneously to maintain consistent temperature during the process. Although Leonardo was never able to test out this technique, François Girardon's colossal equestrian of Louis XIV (destroyed during the French Revolution) was cast in Paris in 1699, in a similar way. *See also* DONATELLO; GHIBERTI, LORENZO; INVENTIONS.

SCYTHED CHARIOT. The scythed chariot was an ancient war vehicle where large iron scythe blades were mounted on either side of a chariot pulled by four horses. Used by the ancient Chinese and Persian armies, the chariots would charge into the infantry lines when a battle was taking place on a large, flat terrain. Eventually, ancient Romans invented a nailed hook that could be thrown onto the ground to injure horses' hooves to slow their progress. While working for Duke **Lodovico Sforza** in **Milan**, Leonardo revisited the scythed chariot, and offered adjustments to minimize its weaknesses. A full-page drawing in the Biblioteca Reale in Turin shows the chariot racing across the bottom of the page, while above we see how the scythe blades rotate to cut down the enemy. Here Leonardo has drawn several dismembered people lying on the ground. *See also* AUTOMATON, BOATS; BRIDGE; CANNONS; DIVING SUIT; ENGINEERING, INVENTIONS; TANK; THIRTY-THREE BARREL ORGAN, WHEEL-LOCK MUSKET.

SELF-PROPELLED CART. Leonardo's self-propelled cart is thought to have been the first automatic machine he designed and is considered to anticipate the invention of the modern automobile. A drawing of the machine appears in his ***Codex Atlanticus***, fol. 812r, and was probably designed in about 1478–1480, when Leonardo would have been establishing his independent career in **Florence** while living with the **Medici**, perhaps attending the **Platonic Academy**, and receiving his earliest independent painting commissions. Leonardo ultimately never finished his **paintings**, and when he was first introduced to Duke **Lodovico Sforza** of **Milan** in 1482, he described himself as an engineer who could also paint. It is likely that Leonardo began his mechanical studies while in the workshop of **Andrea del Verrocchio** and continued these studies as soon as he established his own workshop in Florence.

Leonardo described this machine as a "mechanism," and it was likely intended for a theater setting, but there is no documentation of it ever being constructed. At the top of the sheet is a sketch of the cart, which is incomplete, with its wheels loosely drawn in. The second drawing beneath shows a close-up view of the gear mechanism, seen from above as it would have lain in the cart perpendicular

to the ground. This type of system would have already been well known in **clock** mechanisms, and it featured a similar balancing wheel. The coiled springs would be wound up to move the cart, and the springs could also move levers to control a set of puppets. Moreover, the engine had a steering and braking system for a remote-control hand brake and preset turning ability. A functional model of this cart was first made in 2004, after many unsuccessful attempts throughout the years, and is located in several exhibitions, notably the Istituto di Storia della Science in Florence. *See also* AUTOMATON, ENGINEERING; INVENTIONS; MUSEUMS.

SESTO, CESARE DA (1477–1523). Lombard painter Cesare da Sesto was born in a small town outside Varese and worked in **Milan** in the style of Leonardo. He may have studied with Baldassare Peruzzi in **Rome**, which would explain his more Mannerist treatment of line and **color**. After working in Rome, he likely returned to Milan, where he was introduced to Leonardo's style. By 1514, he had settled between Naples and Messina for six years, and then he returned to Milan, where he established a workshop and painted a standing figure of *Salome*, of which there are two versions, one located in the Kunsthistorisches Museum in Vienna and the other of similar quality in the National Gallery in London, both date to c. 1510–1520.

His *Leda and the Swan*, c. 1505–1510, in the Wilton House, Salisbury, is a copy made from a lost work by Leonardo. This painting depicts a standing nude figure of Leda, with her legs in contrapposto, while her arms twine around the long neck of a swan. Lying on the ground are two pairs of babies that appear to have hatched from eggs, and Leda looks down at the children with a smile on her face. The landscape behind the figures tilts downward toward a path that meanders past homes and clumps of trees toward a beautifully rendered **atmospheric perspective**. While the distant mountains appear in a blue-gray ash, the majority of the **oil** painting is softly modeled in the brown, white, and tan colors characteristic of Leonardo's Milanese work.

Leonardo's lost ***Leda and the Swan*** was copied by many other artists, including Sienese artist Il Sodoma (1477–1549) and Lombard painters **Francesco Melzi** and **Giampietrino**. These artists would have been familiar with Leonardo's **drawings** of this classical subject from c. 1503–1510, when he drew several versions with two different compositions, one of Leda kneeling on the ground with her children and a later version of Leda standing with the swan from 1508. This second composition is documented as having been completed in a painting by Leonardo mentioned in 1625, by Cassiano dal Pozzo, and located in the French royal collection at Fontainebleau. It must have been destroyed later on. Numerous copies exist of both versions, however. Cesare's career is characterized by a lifelong interest in Leonardo's painting style, which he introduced to Southern Italy. *See also BACCHUS*; CLASSICISM; LANDSCAPES, LEONARDESCHI.

SFORZA, LODOVICO (1452–1508). Lodovico Sforza was Leonardo's most important patron, and Leonardo worked for him for 17 years, during which time he completed his most famous works of art, while producing an extensive body of scientific research. The Sforza family dynasty arose from a feudal-era noble class of mercenary soldiers in Lombardy to rule **Milan** beginning with the first duke of Milan, Francesco I Sforza, who took control in 1450, at the end of the Visconti family dynasty. Leonardo's main art patron was Lodovico Sforza, the fourth son of Francesco I. Also known as Lodovio "il Moro," because of his dark complexion, Lodovico was best known for his cultivation of an artistic court in Milan during the 1480s and 1490s, rivaling that of **Florence**. Lodovico was tutored as a young man by humanist scholar **Francesco Filelfo**, and this early education in both art and warfare laid a foundation for his successful rule. After wresting control of the Duchy from his oldest brother Galeazzo, Maria's young son, Lodovico first ruled as regent and then as duke beginning in 1494, until he was driven out of Milan by the French in 1499.

Lodovico employed Leonardo in 1482, when the artist first came to Milan with a silver

lyre commissioned by Lorenzo de' **Medici**, to be delivered by Leonardo as a peace offering. Lodovico was occupied with expanding agricultural industries around Milan, as well as building canals to bring water into the city and expanding fortifications, while continuing work on the **Milan Cathedral** and transforming the Sforza home from a late medieval castle into a **Renaissance** palace, and he hired Leonardo as his chief military engineer. When Lodovico married Beatrice d'Este in 1491 she also worked to craft a sophisticated Milanese court of artists and scholars. Leonardo worked for the Sforza until the fall of Milan in 1499, and his large workshop was busy with commissions for panel **paintings**, wall murals, temporary machines, as well as decorations for festivals, military **inventions**, and weapons. He also found time to work on his scientific studies of nature and **anatomy**, while completing his most famous paintings, the ***Last Supper***, ***Lady with an Ermine***, and the ***Mona Lisa***, as well as the heavily damaged wall murals in the **Sala delle Asse** in the Castello Sforzesco.

Lodovico also commissioned Leonardo to complete a bronze equestrian monument commemorating his father, Francesco I, but nothing of this project remains except for **drawings** of rearing horse and riders. Leonardo collaborated with many artists and scholars in Milan, including the mathematical **Luca Pacioli** and architect **Donato Bramante**, with whom Leonardo might have helped design the main square in Vigevano, a small town in Pavia where Lodovico was born. Under his patronage, Bramante and Leonardo designed the Piazza Ducale beginning in 1492, and Bramante renovated the Visconti castle into an elegant fortified palace for the Sforza. The piazza, which stood in front of the Castello Sforzesco, is visually unified with the castle via the open arcades that surround the square, an early example of Renaissance town planning. Leonardo's work in Milan corresponded with a vibrant time period both culturally and economically, and there he was given the freedom to expand his knowledge in many different directions. Although the Medici were instrumental in helping Leonardo establish his career, the Sforza provided him the opportunities needed to sustain a lifetime of work. *See also* ARCHITECTURE; ENGINEERING, HUMANISM, MATHEMATICS; PORTRAITS, SCULPTURE.

SFUMATO. The term *sfumato* derives from the Italian word *fumo*, which means smoke, and it refers to a smokiness or haziness that gives a sense of atmospheric softness to paintings. This technique requires highly detailed, gradual shading that blends **colors** and tones so the outlines of figures and objects are not visible. Instead, they appear in a space that seems to be created from a warm glow of **light** that reveals a more fully three-dimensional form and superior surface shine. This technique, made famous by Leonardo, was more advanced in its realism than the brightly colored linear style of the Florentine painters of the 1400s. *Sfumato* anticipated the **chiaroscuro** of the next century, where a more dramatic contrast between light and dark was used to model figures by showing more direct light falling onto surfaces that curved into darkness. *See also ADORATION OF THE MAGI*; ANTONELLO DA MESSINA; ATMOSPHERIC PERSPECTIVE; BELLINI, GIOVANNI, BOLTRAFFIO, GIOVANNI ANTONIO; CLEVE, JOOS VAN; FLORENCE, *GINEVRA DE' BENCI*; *LAST SUPPER*; LEONARDESCHI; *MADONNA LITTA*; *MONA LISA*, OIL, OPTICS; PAINTINGS; PORTRAITS; RENAISSANCE; VENICE.

SHIPS. *See* BOATS; INVENTIONS, WEAPONS.

SLINGSHOT. *See* AUTOMATON; BOATS; BRIDGES; CANNONS; DIVING SUIT, INVENTIONS, SCYTHED CHARIOT, 33-BARREL ORGAN, TANK WHEEL-LOCK MUSKET.

SODERINI, PIERO (1450–1522). Piero Soderini was an Italian politician born to a family of doctors in **Florence**. In 1481, he was elected prior of Florence and then ambassador to France under the patronage of Piero di Lorenzo de' **Medici**. The Medici were expelled from the city in 1494, after failing to negotiate a suitable peace with the army of King Charles VIII of France while on their way through Tuscany to lay claim to the Kingdom of Naples, which created a power vacuum that aided **Girolamo**

Savonarola in his brief rise to power. In 1502, the Republic of Florence was reestablished, with Soderini elected as gonfalonier, and Piero made a number of changes to Florentine government, including strengthening the military and expanding government participation among a broader group of citizens. A large audience room had been built on the first floor of the Palazzo Vecchio in Florence to accommodate the new government established by Savonarola in 1494, called the Council of Five Hundred, and in 1504, Soderini commissioned Leonardo to paint the ***Battle of Anghiari*** on one long wall, while **Michelangelo** was commissioned to paint the *Battle of Cascina* on the opposite wall, although neither mural was completed.

Soderini also chose **Niccolò Machiavelli** as ambassador to **Rome** and France, and it was likely because of this appointment that Leonardo had the opportunity to meet Machiavelli while working for **Cesare Borgia**, the son of Pope Alexander VI. In 1512, the Medici returned to Florence and deposed Soderini. Once Pope **Leo X** was elected in 1513, he called Soderini to Rome, and Soderini lived there the rest of his life, where he likely met Leonardo again. *See also* INVENTIONS; WORLD MAP.

SOLAR POWER. During the time Leonardo worked in **Rome**, he continued his canal studies and also experimented with the use of concave mirrors to quicken the heating of water, thereby anticipating future developments in solar power. This technique is still used today in solar plants and is called concentrating solar power (CSP). Leonardo was primarily interested in reducing the amount of wood needed to heat water because he was concerned with deforestation. His ***Codex Arundel***, fol. 86v 87r, shows a double page study of concave mirrors, while his ***Codex Atlanticus***, fol. 1055r, shows a diagram of the reflection lines of a concave mirror, in addition to a tool used to wind up silk thread. On fol. 512r of the same codex, Leonardo reveals the origins of his interest in concave mirrors by showing a mathematical problem from Arab scientist Alhazen's *Book of Optics* from the 11th century, which had just been translated into Italian in the late 1300s, and called *Deli Aspecti*, in which Alhazen sought to calculate the angle of incidence on a concave mirror. Clearly, Leonardo's mirror studies were originally of interest for optical studies, but at some point, he expanded his mirror studies to include their use to direct the sun's heat as an energy source. *See also* CHEMISTRY; INVENTIONS, LEO X; MATHEMATICS; OPTICS; PERSPECTIVE.

SOLARIO, ANDREA. *See* LEONARDESCHI.

STEAM CANNON. *See* CANNONS.

SUBMARINE. Leonardo invented many different types of war machines for both offensive and defensive tactics. In addition to fortifying ships against attacks and wrecks, he also theorized a semisubmersible boat, found in the ***Codex Atlanticus***, fol. 881r. Leonardo designed this work in about 1515, perhaps for the Republic of **Venice** since the city was at war with the Turks, who arrived by sea. Leonardo was illusive in his description of the project, perhaps to keep it secret, and he worried about its ability to inflict cruel punishment on the enemy.

This small boat had room for one person and was covered by a lid and a short, armored tower with a periscope that would remain above water when the shell was submerged. Leonardo wrote that this boat could be used to sink another ship and was therefore considered an attack vessel. The submarine was designed to be tied with ropes to the side of another larger fishing boat, and it had two buoys to stabilize the submarine and provide oxygen for the diver while underwater. Once the fishing boat was close to the enemy ship, the submarine would be detached and the diver could approach an enemy ship by navigating with foot paddles toward the hull of the vessel. There he could dive underwater to sabotage the lining of the ship, undetected. In 1578, William Bourne created the first functional design for a submersible boat, and in 1620, the first submarine was successfully launched on the Thames River. These later **submarines** were indebted to Leonardo's first conceptual design. *See also* BOATS; DIVING SUIT, DOUBLE HULL; INVENTIONS; WATER STUDIES.

T

33-BARREL ORGAN. In the ***Codex Atlanticus***, fol. 67v, we find a sketch of a multibarreled cannon that allowed for quicker loading. Leonardo worked on several different solutions for the slow loading and firing of **cannons**, including the triple-barrel cannon. Here he uses the same idea for multibarreled guns, where his sketch shows three rows of 11 guns attached together and set on a rotating wheeled platform. The guns would be loaded, then one row would be fired, the platform rotated, and the next row fired. One row can be loaded, one fired, and one cooled at the same time. The rows of long barrels resemble the pipes of an organ, which Leonardo could have theorized based on his background in **music**. Like most of Leonardo's military equipment, this organ was never made or used, but it is considered to anticipate the modern machine gun. *See also* ENGINEERING; INVENTIONS; WHEEL-LOCK MUSKET.

TANK. Leonardo's tank is an armored vehicle that can move men into battle and allow them to attack their enemy while protected. This vehicle was designed while Leonardo worked in **Milan** for Duke **Lodovico Sforza** in about 1487, and is considered a prototype for the modern tank. It appears in a drawing in the Biblioteca Reale in Turin, fol. 1030. Leonardo's sketch shows a vehicle with a conical covering made of wood covered by metal sheets that could move in any direction. The basic idea recalls a turtle shell. Inside, the vehicle could be moved by four to eight men with two large cranks and had small **cannons** around the lower exterior and a covered opening at the top for sighting. In Leonardo's sketch, the gears are in reverse order, and some scholars have speculated that Leonardo drew them incorrectly on purpose to hide his design from enemies. Ultimately, the vehicle was never built. It could not have traveled quickly or on rough terrain, so the idea was not reexamined until the modern age of warfare, when tanks were introduced in World War I. Leonardo's design, however, was discovered to be superior due to its sloped plate, which aided in deflecting ammunitions. *See also* AUTOMATON; BOATS; BRIDGES; CANNONS; DIVING SUIT; ENGINEERING; INVENTIONS, SCYTHED CHARIOT, 33-BARREL ORGAN, TANK, WHEEL-LOCK MUSKET.

TEMPERA. While Leonardo favored **oil** paint, he also used tempera, which is called egg tempera. This paint consists of a mixture of ground pigment and egg yolk and/or egg white, which is used as the binding agent to attach the **color** to a wood panel or other painted surface. Tempera dries more quickly than oil paint and does not allow as subtle a gradation of color but is highly stable; however, it provides a thinner pigment that can be used to create highly detailed works with very small brushstrokes. Because Leonardo sought a highly realistic pictorial imagery that reflected his scientific studies of the physical world, he frequently experimented with color recipes, sometimes with disastrous results. Nonetheless, his mixture of egg and linseed oil offered him the ability to create both the detailed work and color variation needed for a realistic style.

See also CHIAROSCURO, FRESCO; PAINTINGS; PORTRAITS.

TIME MACHINE. In the ***Paris Manuscript*** B, fols. 33v and 34r, are several curious sketches that seem to refer to a time machine. It is a perpetual motion machine, but it has never been adequately explained or built. Modern recreations show a wooden machine that rotates like a Ferris wheel, with boxes attached that resemble the passenger cars. Leonardo wrote little about his time devices, but it seems this would have been inspired by a traditional hour glass, where sand moves from the top of a glass tube through a tight space into the bottom tube in approximately one hour. In this case, sand or a liquid like water would have filled the boxes and the boxes rotated around the wheel clockwise, but once the boxes rotated halfway around, they would reverse direction with a hitching devise and return to their original location, now going counterclockwise. In addition, as the boxes moved back in place, they would tilt on an angle, thereby shifting the weight of the machine to its side, making the wheel start to spin on its own and rotate without the help of a gear system.

This idea was a theoretical study that did not take friction into account, which would have eventually stopped the machine. The energy generated from this machine would ultimately have been superior to a water mill, since it wouldn't have required an infinite supply of water, and its perpetual motion could have been used to power the winding of a clock, which is why it is called a time machine. *See also* CLOCKS ENGINEERING; INVENTIONS

TOBIAS AND THE ANGEL. This small painting, located in the National Gallery in London, is attributed to the workshop of **Andrea del Verrocchio** from about 1470–1475. The subject shows Tobias, sent by his blind father Tobit to collect a debt, accompanied by the Angel Raphael. The Angel tells Tobias that he can cure his father's blindness with a recipe made from fish organs. Some scholars consider the work an early painting by Leonardo, but that attribution is not universally accepted. The subject and composition are based on an earlier work by **Antonio del Pollaiuolo,** and Leonardo scholar **Martin Kemp** has suggested that Leonardo may have painted some of the work, including the fish, while working in Verrocchio's studio, which would place this work as the first known painting in Leonardo's career. Both the fish and the dog demonstrate a sophisticated understanding of volume and shadow similar to Leonardo's early work in **Florence.** The Confraternity of Saint Raphael was popular in Florence in the 1400s, so this work could well have been a chapel commission from this religious organization. *See also* CATHOLICISM; PAINTINGS.

TOPOLOGY. Topology is a mathematical field of study described in this ancient Greek word as the study of the properties of space as it changes through stretching, bending, and collapsing. It is a subfield of **geometry** that emerged as a discipline in the early 20th century, but some of Leonardo's ideas on geometry anticipate topology. Specifically, his drawings of tangled knots and loops, found in six images located in the Accademia Vinciana, which were done in the 1490s during Leonardo's stay in **Milan,** show his early interest in entangled designs. **Giorgio Vasari** described these designs as a series of knots made from one single rope that can be traced through the knot from beginning to end, but, in fact, they are made from a series of loops. These *cartelle* were later copied by **Albrecht Dürer,** and regular knots, although not mathematical, appear in the embroidery on ***Mona Lisa's*** bodice, and in the tablecloth knot in Leonardo's ***Last Supper.*** Although these knots do not show conclusively that Leonardo understood the mathematical principles of topology, they do demonstrate Leonardo's interest in continuous transformations of space and objects, and how they are connected.

Leonardo also made numerous sketches of the measurement of solid bodies and how changes to their shapes affect their volume, as seen specifically in a section of the ***Codex Forster*** done in Florence, called the *Libro titolato de strasformatione,* dated July 1505, which show some topological transformations. During his later years, Leonardo was

increasingly interested in what he called "geometry in motion" and wrote a series of geometry games called *De ludo geometrico* on a large double folio in the ***Codex Atlanticus***. While early art historians considered these shape transformations a mere game, or doodles done by an artist past his prime, scholars now understand these **drawings** to be the beginning of a treatise on geometry. *See also* CLASSICISM; MATHEMATICS; PACIOLI, LUCA.

TORRE, MARCANTONIO DELLA (1481–1511). Marcantonio della Torre was an **anatomy** professor at the University of Pavia and the University of Padua during the early 1500s, and he worked with Leonardo in **Milan** to write a treatise on human anatomy informed by highly realistic **drawings**. Although the treatise was never written, Leonardo mentioned his plans in a painting treatise he planned to publish. Together they dissected corpses throughout the winter of 1510, and Leonardo eventually made more than 750 anatomical drawings during his lifetime. After della Torre's death from the plague in 1511, Leonardo's drawings were scattered through his codices, never to be assembled for publication. **Giorgio Vasari** and **Paolo Giovio** both described the working relationship between the anatomist and the artist, but no known published work exists by della Torre. *See also* BIOMECHANICS; NOTEBOOKS, PHYSIOLOGY; *TREATISE ON PAINTING*; VESALIUS, ANDREAS.

TREATISE ON PAINTING. Leonardo wrote a series of essays on the subject of painting, called the *Trattato della Pittura*, and after his death these writings, simply called "On Painting," were gathered together by the artist's apprentice, **Francesco Melzi**, who organized them into a collection now called the *Codex Urbinas* 1270, housed in the Biblioteca Apostolica Vaticana in **Rome**. Melzi planned to publish the manuscript in about 1540, but instead it stayed in his family after his death and then reappeared in the private collection of the Della Rovere family, where it changed hands several times before entering the Vatican Library.

An abridged version of Leonardo's writings on painting was printed in Paris in 1651 (Raffaele Du Fresne, *Trattato della pittura di Leonardo da Vinci* [Paris: Giacomo Langlois, 1651]), based on a copy extracted from the original manuscript that entered the collection of Cassiano Dal Pozzo, who oversaw its publication in Paris, together with a biography of Leonardo written by Giovanni Ambrogio Mazenta, a Milanese friar who briefly owned the manuscript in the 1620s. This copy is now in the Ambrosiana Library in **Milan**. Meanwhile, the original Vatican manuscript was rediscovered in the late 1700s and published in Rome in 1817 (Giovanni Gherardo de Rossi and Guglielmo Manzi, eds., *Trattato della Pittura di Lionardo da Vinci tratto da un codice della Biblioteca Vaticana* [Rome. Stamperia de Romanis, 1817]). Eighteen original manuscripts are listed at the end of the codex, of which six are extant. **Luca Pacioli** mentioned in 1498, that Leonardo had completed a treatise on painting and human emotion, which could be ***Paris Manuscript*** A, folios 1–65, which are drafts for a book on painting organized by Melzi, while **Giovanni Paolo Lomazzo** confirmed in 1584, that Leonardo had written such a treatise for Duke **Lodovico Sforza**.

Leonardo's treatise is focused on a careful, scientific method of observing how to depict the physical world in a realistic pictorial representation. He discussed **color** and shading, composition, and **perspective** in detail, and wrote Leonardo's design principles focused on the idea that the "first principle of the science of painting is the point, the second is the line, the third is the surface, the fourth is the body, which is clothed by these surfaces" (*Libro di pittura*, chapter 5). He also argued for the superiority of painting over poetry and **music**. This *paragone*, or theoretical comparison, is the first debate comparing these particular arts. Leonardo then introduced a second *paragone* on the superiority of painting over **sculpture**, which he argued was because of the use of color, while **Michelangelo** argued that painting merely sought to emulate the three-dimensional qualities inherent in sculpture.

Leonardo also noted that sculpture requires more physical exertion, while painting causes

more mental fatigue. He further explained that the physical difficulty of carving marble requires the artist to strike the stone with great force, causing dust and dirt to gather on the face to make the artist look like a baker covered in flour. While the house of the sculptor is dirty and covered in stone chips, the house of the painter is filled with fine **paintings** and the sound of music and literature being read, while the painter sits at his easel painting with fine colors, wearing whatever clothing he wants. Clearly, in this comparison, Leonardo is allying painting with the intellectual pursuits of the noblemen and humanists of the **Renaissance**, while reminding the reader that sculpture is a manual labor and therefore considered socio-economically inferior.

Leonardo's writings were in line with the ideas of such humanist scholars as **Baldassare Castiglione**, who wrote in *The Book of the Courtier* (published in **Venice** in 1528) that drawing and painting were appropriate skills for courtiers to learn, and Castiglione noted that ancient Greek noblemen sent their children to school to learn painting to recognize the beauty of proper proportions in nature. Leonardo's ideas influenced many artists throughout the 1600s, including Annibale Carracci, Nicholas Poussin, and other artists who favored the classical style through the Baroque era.

TRIPLE-BARREL CANNON. *See* CANNONS.

TRIVULZIO MONUMENT. *See* MILAN; SCULPTURE.

TRUMPET. *See* MUSIC.

U

UCCELLO, PAOLO (c. 1397–1475). Italian **Renaissance** artist Paolo Uccello is known as both a painter and a mathematician interested in **perspective.** He studied with **Lorenzo Ghiberti,** from whom he developed an interest in the careful observation of nature and use of **perspective** to show a compressed narrative with greater clarity. During this time, he also established a friendship with sculptor **Donatello,** who was also known for the way he adjusted the proportions of his **sculptures** to take into account the audience's viewpoint. His earliest work of importance consisted of his cloister **frescoes** from Genesis in the monastery of Santa Maria Novella in **Florence,** from about 1424. In 1425, Uccello traveled to **Venice** for work, from where he traveled to Bologna and also possibly to **Rome.**

Upon his return to Florence, in 1436 the **Medici** commissioned him to paint an equestrian figure of the *condottiero,* or hired military soldier, Sir John Hawkwood (c. 1323–1394). Hawkwood was an English soldier who fought for France before crossing the Alps into Italy, where he served a number of rulers before settling in Florence to die a hero who had fought against the rival Milanese. Uccello's fresco, on the north wall of the nave, depicts the warrior on a horse painted gray-green to resemble an aged bronze monument. Hawkwood is dressed in armor and sits stiffly upright while holding a baton. His horse marches forward with one front leg raised up, and the figure group rests on a tall, classical pedestal with a laudatory inscription written in **Latin.** Uccello clearly envisioned the monument as a sculpture group that rises above the spectator. He used mathematical perspective to show the pedestal at a raking angle from below, where the viewer sees the coffering beneath the platform. This equestrian would have been seen by Leonardo, who later developed his interest in equestrian sculptures into a colossal bronze horse and rider commissioned by Duke **Lodovico Sforza** of Milan, which was never completed.

Uccello's most famous painting are his three scenes of the *Battle of San Romano,* painted sometime between 1435–1460. The scenes represent a famous Florentine battle won against the Sienese in 1432, and the paintings, commissioned by the Bartolini Salimbeni family, were stolen by Lorenzo de' Medici after he attempted to purchase them with the agreement of one owner but not the other. The best-known version shows mercenary soldier Niccolò da Tolentino, riding a white horse and wearing a big red hat, instructing his army, seen in armor, to drive forward into battle. What is interesting about this scene is how Uccello attempted to organize the otherwise chaotic battle scene in a pictorial narrative tradition, taking into account how the viewer will understand the action. In a scene otherwise impossible to codify with **linear perspective,** Uccello arranges fallen lances on the ground, set at 90-degree angles to create a grid. The ground glows a white-pink color to highlight the lances, which would normally be buried and therefore not visible lying in dirt and grass. To the viewer's left foreground, a soldier lies on the ground, having died in perfect mathematical perspective. Meanwhile, the background,

rather than receding back into an **atmospheric perspective**, rises up like a tapestry to bring the viewer's eye back to the foreground narrative.

In this painting, Uccello shows us the flaws of mathematical perspective, which does not work in the organic, natural landscape and is limited to what the eye can see and interpret. Movement cannot be accurately depicted, for example, because the sight lines would be constantly in motion. Clearly, Leonardo was influenced by these types of battle scenes in his ***Battle of Anghiari***, from c. 1505. Furthermore, Leonardo sought to resolve some of these issues with mathematical perspective by creating a three point system to allow for greater movement and by modeling his figures with **chiaroscuro** to show depth in a more convincing way. *See also* BOTTICELLI, SANDRO; CASTAGNO, ANDREA DEL; GHIRLANDAIO, DOMENICO; LANDSCAPES; MATHEMATICS; POLLAIUOLO, ANTONIO DEL, SCULPTURE; VERROCCHIO, ANDREA DEL.

URBAN PLANNING. *See* IDEAL CITY.

V

VASARI, GIORGIO (1511–1574). Italian **Renaissance** painter, architect, and historian Giorgio Vasari was born in Arezzo and moved to **Florence** at the age of 16, to establish a painting career in the Mannerist style. He is best known for his *Lives of the Most Excellent Painters, Sculptors, and Architects*, which was the first biographical examination of artists written in an encyclopedia format. This text provides an important window into the lives of Italian artists, primarily from Florence, who worked in the late Middle Ages through the early 1500s. Vasari's writing blends biographical data with apocryphal stories, and it was dedicated to Duke Cosimo I de' **Medici** and first published in 1550. Republished multiple times since then, the book remains widely influential throughout Europe.

Vasari's *Lives* favored Florentine artists, who he felt worked in the artistic epicenter of Europe, and his favorite artist was **Michelangelo**, whom he met in Florence, where he wrote an extensive biography of Michelangelo and argued that Michelangelo's work had reached the pinnacle of perfection. Vasari was first to use the word ***Renaissance*** to refer to a rebirth of the arts during this era, and in a later edition, he widened his selection of artists by including Venetian Renaissance painters. Indeed, Vasari's ideas laid the foundation for the discipline of art history and the primacy of Florentine artists that has continued into the modern age, and his value judgments still sway opinions about European Renaissance art to this day.

Leonardo, who was significantly older than both Michelangelo and the younger Vasari, was an important figure in Vasari's *Vite*, which provides some of the only primary evidence of Leonardo's life and artistic career. Despite the fact that Vasari is known to have embellished his stories, his writing has provided important descriptions of some of Leonardo's works that are not extant today, and he confirmed the identity of other **paintings**. Vasari would have known Leonardo's work firsthand, as he was commissioned to paint the walls of the suite of rooms for Cosimo I de' **Medici** in the Palazzo Vecchio in Florence, completed in 1547, located upstairs from the Salone dei Cinquecento, where Leonardo's abandoned ***Battle of Anghiari*** mural was designed opposite Michelangelo's *Battle of Cascina*. Leonardo first appeared in Vasari's biography of **Andrea del Verrocchio**, where Vasari described Leonardo as Andrea's most promising pupil. He then went on to lavish praise on Leonardo, who he described as beautiful, graceful, and with a powerful intellect. He noted, however, that because Leonardo "set himself to learn many things," he would often abandon them.

Leonardo learned arithmetic, **music**, and art with ease at a young age, and so his father, Ser Piero da Vinci, sent him to work with Verrocchio. Vasari first attributed the angel head in Verrocchio's *Baptism of Christ* to Leonardo, which is widely confirmed through stylistic examination. Vasari then mentioned other works that are not extant, including a shield with a head of Medusa and a silver lyre. Next, he described Leonardo's time in **Milan**, where one patron complained that Leonardo was often lost in thought and unable to complete

commissions. Leonardo explained to Duke **Lodovico Sforza** that men of genius needed to work things out first in their minds and then with their hands. Vasari mentioned many of the **inventions** and projects Leonardo worked on in Florence, and noted that Leonardo explained his inventions with such strong reasoning that people rarely realized how impossible many of his ideas were. Vasari's biography of Leonardo laid the framework for understanding Leonardo's life and paintings; interactions with family, friends, and patrons; and working ideas and influences. *See also ADAM AND EVE*, ALBERTINI, FRANCESCO; BOTTICELLI, SANDRO; CARICATURES; CASTAGNO, ANDREA DEL; CLASSICISM; FRANCIS I; FREY, KARL OTTO; GHIRLANDAIO, DOMENICO; GIOVIO, PAOLO; HUMANISM; LOMAZZO, GIOVANNI PAOLO; MEDUSA SHIELD; MICHELANGELO BUONARROTI; *MONA LISA*; POLLAIUOLO, ANTONIO DEL; UCCELLO, PAOLO; VEGETARIANISM; VENICE; *VIRGIN AND CHILD WITH SAINT ANNE AND SAINT JOHN THE BAPTIST*.

VEGETARIANISM. There is no proof that Leonardo was a vegetarian, but it is an idea that has gained traction throughout the years as scholars have attempted to better understand Leonardo's personal life, goals, and interests. Throughout his writings he described his admiration for animals, and at one point, in a section called "Prophecies," he talks about the cruelties of man. In his ***Codex Atlanticus***, he specifically brought up the ethics of eating meat and described the suffering of animals separated from their young. Furthermore, early biographer **Giorgio Vasari** described how Leonardo would purchase and free caged birds he found at local markets, and in a letter written by explorer Andrea Corsali to Giuliano de' **Medici** while traveling through the East Indies, Corsali described a group of native peoples who did not harm living creatures, nor did they eat any living creature that produces blood, and Corsali went on to note this similarity to Leonardo. Corsali likely never met Leonardo, and no response from Giuliano de' Medici confirms his casual observation.

Nonetheless, the idea that Leonardo was a vegetarian gained traction in later tales of historical fiction written about him and even entered some scholarly biographies, including those written by Serge Bramly and Alessandro Vezzosi. Other scholars have suggested that Leonardo could not have been a vegetarian, given that his work in designing machines of war invalidated the notion that he was a pacifist. Some scholars note that Leonardo's grocery lists typically mention meat, which, of course, could have fed his household, while others have suggested that Leonardo might have been a vegan, but this notion must certainly be discounted given that Leonardo did mention eating cheese and eggs, and the concept of veganism was largely unknown until recently. *See also* FICINO, MARSILIO; NOTEBOOKS

VENICE. Leonardo spent a short time in the Republic of Venice, known as "La Serenissima," but while there he became acquainted with the particular style of Venetian painting of the late 1400s, which favored landscape views with an **atmospheric perspective** similar to his optical interests. Furthermore, Venetian artists had access to new **colors** imported into their port city, and they were first to experiment with the hazy atmosphere made famous by Leonardo called **sfumato**.

Venice is located on the Adriatic Sea, and its trade routes to the Byzantine Empire and farther east made the people enormously wealthy and their culture international. Most of the commerce coming into Italy came through Venice in more than 3,000 ships owned by wealthy families and the government. The Venetian government was overseen by these merchant and aristocratic families, who traced their families back to ancient Rome and ruled as the Great Council. Members of this council elected more than 200 members of the Senate, who then appointed 10 members from their group as their executive board, called the Council of Ten, from which the doge, or duke, was selected. Venice was an important commercial center with trade secrets held in the production of glass; a vast amount of imported goods, including spices, silks, and grain; and the largest printing presses in Italy. When Constantinople fell to the Muslims in 1453, an

influx of Greek scholars and artists flooded Venice, and the city also became an important intellectual center for the translation of ancient Greek manuscripts

Leonardo arrived in Venice in 1500, after fleeing the French entry into **Milan** in late 1499. After stopping for a few months in **Mantua**, he and the mathematician **Luca Pacioli** arrived in Venice early that year. Once there, Leonardo introduced himself to the council and offered his services as a military engineer. He suggested he could construct a dam whereby the Venetian navy could draw the Turkish army into the Isonzo River valley and then flood the valley to drown the army. Too expensive and impractical, Leonardo shifted his attention to a plan for an underwater attack on Turkish ships where Venetian divers, wearing **diving suits** Leonardo designed, could swim underwater and puncture their ship hulls. None of these plans came to fruition, and by April 1500, Leonardo had returned to Florence. These **inventions** were later revisited when scuba gear was introduced and more sophisticated navy tactics were devised.

Certainly, Venice would also have been the inspiration for Leonardo in his designs for the port canal of Cesanatico, located on the Adriatic coast south of the ancient city of Ravenna. In 1502, **Cesare Borgia** commissioned Leonardo to survey the area and design a port attached to the canal that reached to the town of Cesena about nine miles away. Today the small town is a tourist hub nicknamed Leonardo's "Little Venice." *See also* ANTONELLO DA MESSINA; BELLINI, GIOVANNI; BOATS; BRIDGES; CANAL LOCK; DÜRER, ALBRECHT; FILELFO, FRANCESCO; HYDRAULICS; MANTEGNA, ANDREA; SUBMARINE; VERROCCHIO, ANDREA DEL.

VERROCCHIO, ANDREA DEL (c. 1435–1488). Andrea di Michele di Francesco de' Cioni, nicknamed Verrocchio, or "true eye," because of his superior drawing skills, oversaw one of the most important workshops in **Florence** in the 1470s–1480s, specializing in panel and **fresco** painting and bronze casting. Verrocchio was born in Florence to a bricklayer and apprenticed to a goldsmith early on. Little is known of his early life, but later in his career he was supported by Lorenzo and Piero de' **Medici**, whose patronage elevated him to international fame.

Leonardo entered Verrocchio's workshop in about 1466–1468, during his teenage years, and he first learned to work in a variety of materials before collaborating with Verrocchio on several early panel paintings. **Giorgio Vasari** attributed the left angel in Verrocchio's *Baptism of Christ*, c. 1475 (Florence, Uffizi Gallery), to the youthful Leonardo, and this has been widely confirmed based on stylistic analysis. In this **oil** and **tempera** poplar panel painting, 69.7 x 59.4 inches, John the Baptist is seen at the viewer's right stepping into a shallow pool of water to baptize Christ, who appears in the center of the painting with his hands held together in prayer. Above Christ's halo, John's hand tilts a shallow bowl of water while golden rays of **light** flare out from the Holy Spirit, symbolized by a white dove that emerges from the hands of God. To the viewer's left, two angels kneel at the bank of the creek. Christ's muscles and the Baptist's visible rib cage both demonstrate Verrocchio's study of human **anatomy**, while the landscape that stretches beyond the foreground figures extends back into space with **atmospheric perspective.** Water ripples around the ankles of Christ and the Baptist, and smooth pebbles line the shore next to the angels, which reveal Verrocchio's careful study of nature and his mastery of realism.

A comparison of the heads of the two angels shows two different styles and, thus, the work of two different artists, which was common during this time, when masters relied on shop assistants to prepare the wood panels, mix the **colors**, and even paint portions of a scene. The angel to the viewer's right turns to gaze left, while the angel far to the left, attributed to Leonardo, reveals a superior sense of space and volume. Leonardo's angel faces away from the viewer but looks left over his shoulder in a three-quarter profile that also tilts upward toward the standing John the Baptist. Here, Leonardo shows an understanding of how the head can function as a sphere turning in space. While most artists studied **geometry**

during this time, Leonardo's early mathematical studies allowed him to elevate the style of realism to a higher degree of visual accuracy in this work. This work could have been made for the Monastery of San Salvi outside Florence, and several **drawings** are associated with the painting, including a head of an angel (Turin, Biblioteca Reale, inv. 15635), a drapery study in the Louvre (inv. 2256, p. 15), and a drapery study in Florence (Uffizi Gallery, Gabinetto Disegni e Stampe inv. 420E).

Many of Verrocchio's works have been examined to detect the early hand of Leonardo. These include a *Madonna and Child with Angels* from c. 1470 (oil on panel, London, National Gallery), where Leonardo perhaps painted the lily and the landscape background; a *Madonna and Child* (oil on panel, Berlin, Staatliche Museen Gemäldegalerie), where Leonardo might have painted the rocks on the viewer's right; a *Madonna and Child* (oil on panel, Berlin, Staatliche Museen, Preussischer Kulturbesitz), where Leonardo perhaps painted the mountains to the viewer's left; and a workshop painting of *Tobias and the Angel* (oil on panel, London, National Gallery), where Leonardo might have painted the fish and the dog.

Verrocchio belonged to the **Confraternity of Saint Luke** and was primarily known as a goldsmith. In the 1460s–1470s, he designed the funerary monuments for Cosimo, Piero, and Giovanni de' Medici in their family church of San Lorenzo in Florence, and in 1468, he made a golden ball for the lantern of the Florence Cathedral from sheets of copper soldered together and gilded. In the 1460s, he was also commissioned to cast a bronze figure of *David* for Piero de' Medici, which was purchased by the Florentine government in 1476. Unlike Donatello's *David*, Verrocchio's young man poses in a contrapposto stance with the head of Goliath at his feet. He wears an armored tunic and holds a short sword. It has been suggested that the young Leonardo was his model for this work, and indeed the young David appears to be the same age as Leonardo was then.

In 1483, Verrocchio won a competition for a bronze equestrian monument of mercenary soldier Bartolomeo Colleoni, the military general for the Republic of **Venice**, who had left a substantial amount of money in his will for the monument. Thus, Verrocchio opened a foundry in Venice and left his Florence studio to **Lorenzo di Credi**. He completed the final clay model just before his death in 1488, and it was cast in bronze to his design by Venetian sculptor Alessandro Leopardi (1466–1512), who also made the tall pedestal for its placement in the square of the church of Santi Giovanni e Paolo in Venice. **Donatello's** equestrian of Erasmo da Narni, completed 35 years earlier in 1453, served as an important precedent for this type of monument. Based on the classical subject, Donatello's figure reveals a calm, quiet resolve as he marches into battle, while Verrocchio's figure is more energized as Colleoni's horse strides forward on three legs while tense muscles ripple across his body. Colleoni glares off into the distance, as if he is ready to spring into action. Clearly, Verrocchio knew that the two works, located in nearby cities in the Veneto, would be compared, and

Andrea del Verrocchio, *Baptism of Christ*, c. 1475, oil and tempera on poplar panel, 69 7 x 59 4 inches, Florence, Uffizi Gallery.

so he offered a variant on Donatello's **sculpture**, demonstrating a higher level of skill by resting the weight of the bronze on three legs rather than four.

Leonardo was very interested in the technical challenges of bronze casting, and in the 1490s he planned what would have been the largest horse ever made, to be cast in one piece. Furthermore, Leonardo also studied the anatomy of the horse and sought to design a sculpture where the horse would rear up on two legs. Although Leonardo's sculptures were not realized in his lifetime, his designs set up technical challenges that continued to inspire sculptors into the next several centuries. *See also ADAM AND EVE; ANNUNCIATION;* BODE, WILHELM VON; BRUNELLESCHI, FILIPPO; COLOR; CRANES; FRESCO; GHIRLANDAIO, DOMENICO; POLLAIUOLO, ANTONIO DEL; WAAGEN, GUSTAV FRIEDRICH.

VESALIUS, ANDREAS (1514–1564). **Renaissance** anatomist Andries van Wesel (Latinized to Andreas Vesalius) is considered the founder of modern human **anatomy**. Born in Brussels during Habsburg rule, Vesalius's great-grandfather, Jan van Wesel, studied medicine at the University of Pavia and taught at the University of Leuven, while his grandfather and father both worked in the medical field for Emperor Maximilian. Vesalius graduated from the University of Padua where he was immediately hired to teach anatomy and surgery. Working in Padua and **Venice**, he was hired as an illustrator and established a method of direct observation through dissections that was based on the work of Leonardo. This was a break from prevailing scientific ideas, which were largely based on classical texts. Leonardo argued that these classical sources must be tested through direct observation, and his dissection work was foundational to the anatomical studies of subsequent scientists. Indeed, some scholars have suggested that had Leonardo's anatomical studies been published in his lifetime, they would have overshadowed the later work of Vesalius. *See also* BIOMECHANICS; NOTEBOOKS; PHYSIOLOGY; TORRE, MARCANTONIO DELLA; *TREATISE ON PAINTING.*

VINCI. Vinci is a small hill town about 30 miles west of **Florence**, in the region of Tuscany, where Leonardo's father lived and where he was raised for a portion of his youth. Today, the town hosts the Museo Leonardiano, which was founded in 1953, inside the Castello dei Conti Guidi, and houses a collection of Leonardo's **drawings** and reconstructed models of his **inventions**, including the bicycle and **parachute**. Leonardo's birthplace in Vinci has also recently been restored to a small museum that houses some of his drawings. The town began as a feudal-era fortified castle built on the slopes of Montalbano in about 1000, for the noble Guidi family, who held vast territories in Central Italy during the late Middle Ages. By the mid-1200s, the town had been taken over by the Republic of Florence, but the castle was raided by various mercenary soldiers, or condottieri, through the 1300s.

Vinci became an agricultural commune in 1372, and remained under Florentine rule. It is best known as the birthplace of Leonardo, and visitors to this small, quiet town generally take a day trip from Florence to visit the museum. Beginning in 1960, the Biblioteca Leonardiana in Vinci has hosted an international conference every spring to examine one of Leonardo's writings in detail. The papers presented at these annual conferences are published by Giunti di Firenze and listed on the Biblioteca Leonardiana website: http://www.biblioteca leonardiana.it/bbl/bb-leo/bb-leo-elenco-pubb.shtml. *See also* KEMP, MARTIN; MEDUSA SHIELD, MUSEUMS; PEDRETTI, CARLO.

VIOLA ORGANISTA. *See* MUSIC

VIRGIN AND CHILD WITH SAINT ANNE. Leonardo's *Virgin and Child with Saint Anne* is a securely attributed **oil**-on-panel painting from c. 1503, now in the Louvre Museum in Paris (66 x 44 in.). The subject depicts the Virgin Mary sitting on her mother Saint Anne's lap while she reaches down to clasp the Infant Christ, who is playing with the ears of a lamb. A deep landscape view unfolds behind the group. This painting was commissioned for the high altar of the Church of Santissima Annunziata in **Florence** in 1500. Leonardo had

first studied this unusual and challenging composition in 1498, in his Burlington Cartoon, a drawing that depicts the ***Virgin and Child with Saint Anne and Saint John the Baptist***, whereby the Infant Christ squirms on his mother's lap, while she, in turn, is seated on the lap of her mother, Saint Anne, while Christ stretches across his mother to interact with his childhood friend and cousin, John the Baptist.

This subject of the Virgin seated on her mother's lap was new and had no symbolic or cultural precedent, except that the three generations echoed the importance of the number three in religious symbolism and Leonardo's work, where the triangular composition favored in earlier **Renaissance** works gains depth by Leonardo's pyramida composition. Furthermore, this composition required a stacking of figures and complexity of pose, which until then had only appeared in battle scenes or mythological narratives. In this work, Leonardo was able to weave together a cohesive family interaction, where Saint Anne turns to smile down at her daughter, who reaches to wrap her arms around the Christ Child protectively. Meanwhile, Christ, seen as an impish, chubby baby—the healthy ideal—smiles back at his mother, while putting his leg over the back of the lamb as if he wants to ride it like a horse. The realism and human connection between these three figures would have engaged the viewer's empathy. *See also* CATHOLICISM; CLOS LUCÉ; PAINTINGS.

Leonardo da Vinci, *Virgin and Child with Saint Anne*, c. 1503, oil on wood, 66 x 44 inches, Paris, Louvre Museum.

VIRGIN AND CHILD WITH SAINT ANNE AND SAINT JOHN THE BAPTIST. This drawing, also called the *Burlington House Cartoon*, is a scale drawing on paper done in charcoal and white chalk with wash on eight pieces of parchment that are glued together. It was later mounted to canvas. It dates to about 1498, measures 55.7 x 41.2 inches, and is in the National Gallery in London. This type of preparatory work would have been common for painters, but these **drawings** were not always preserved, so this cartoon is a rare example of a full-sized drawing used to finalize a painting's composition. Here we see the Virgin Mary seated on the lap of her mother, a challenging composition of stacked figures that interested Leonardo throughout his life. The Christ Child squirms across his mother's lap to bless his cousin, the infant Baptist, who leans his arms on the legs of Anne in a composition similar to the ***Virgin and Child with Saint Anne*** in the Louvre. Saint Anne points to heaven, which reminds the viewer of Christ's importance in our eternal life. The women are stacked such that their legs point in opposite directions, creating a solid pyramidal shape that weaves the composition together with curves that create an effective whole. This cartoon would have been pinned to a primed panel and the outlines incised or pricked and dusted to transfer the outline from the drawing to the panel, which would then be penciled in. Cutting through the cartoon damaged the sketch, which is why most are not extant, but this drawing remains intact likely because Leonardo did not

continue work on the painting, as happened on many other occasions throughout his life.

This cartoon would have been done in **Milan** just before the French invasion of 1499, and **Giorgio Vasari** wrote that a similar cartoon was displayed at the Servite Monastery in Florence in 1501, which could have been the drawing for the Louvre *Virgin and Child with Saint Anne*, while some scholars have suggested that the *Burlington House Cartoon* dates to 1506–1508, when Leonardo lived in Milan but returned frequently to **Florence**. Leonardo's student, **Bernardino Luini**, painted a similar subject, but in his painting Joseph also appears to the viewer's right side (Milan, Biblioteca Ambrosiana). Another of Leonardo's students, **Francesco Melzi**, also borrowed the Virgin's face in his painting of *Pomona and Vertumnus* (Berlin, State Museum).

The cartoon was first documented in the early 1600s, in the collection of Count Galeazzo Arconati (before 1592–after 1648) of Milan, who was one of the early collectors of Leonardo's **notebooks**, including the ***Codex Atlanticus*** and numerous colored drawings for Leonardo's ***Last Supper***, which are dispersed today. After passing through several private collections, the cartoon was brought to London by Robert Udny, the brother of the English ambassador to **Venice**, and later donated to the Royal Academy in London. In the 1960s, funds were raised to transfer the work to the National Gallery in London, where it was vandalized in 1987, but its glass covering now protects the drawing, which has been restored and remains on display. *See also* CATHOLICISM; *MADONNA OF THE YARNWINDER* (*BUCCLEUCH*); PAINTINGS.

Leonardo da Vinci, *Virgin and Child with Saint Anne and Saint John the Baptist (Burlington Cartoon)*, c. 1499–1500, 55 7 x 41 2 inches, charcoal and chalk on paper. London, National Gallery.

VIRGIN OF THE ROCKS. The *Virgin of the Rocks*, or *Madonna of the Rocks*, is an altarpiece painting dated c. 1483–1486 (78.3 x 48 in., **oil** on wood transferred to canvas), located in the Louvre Museum in Paris and universally attributed to Leonardo. Called the Louvre version, it predates the London version, which is generally attributed to Leonardo (c. 1495–1508, 74.6 x 47.25 in., oil on wood), located in the National Gallery. Both **paintings** depict the Madonna kneeling on the ground with her right arm wrapped around the infant John the Baptist, who kneels before the Christ Child with his hands clasped together in prayer. The Christ Child is seated on the ground opposite the Baptist and offers a blessing with the first two fingers of his right hand raised and angled toward his cousin. An angel sits behind Christ and acts as an intercessor, looking out at the viewer while pointing above Christ's head toward the Baptist. Meanwhile, the Virgin holds her left hand out directly above the angel's gesture with her palm facing down over the head of Christ in a gesture of protection. The four figures are arranged in a loose circle surrounded by rocks and vegetation beneath them and a rocky grotto formation behind and above them. The rocks create an imaginary landscape informed by Leonardo's geological interests. The Virgin wears a deep blue-green robe that tugs away from a brooch clasped at her neck to reveal a soft yellow underside, while the angel wears a red robe that billows

slightly. The rest of the work is painted in a restricted palette of dark earth tones with light and dark contrasts.

This subject grew out of the Gospel of Matthew's account of the Virgin, Joseph, and infant Christ's escape from King Herod's massacre of young male children in Bethlehem. Various stories detail how John the Baptist and the Archangel Uriel or Gabriel met them along the way. Leonardo's focus on the rocky background had precedents in earlier Florentine Madonna and Child paintings, for example, the *Madonna and Child* by Filippo Lippi, c. 1445 (Florence, Uffizi Gallery), where the rocks recall the cave setting of many Nativity and Adoration scenes, for instance, those by **Sandro Botticelli**, which would have been familiar to Leonardo.

The large painting, arched at the top, was an altarpiece commission that included side panels of angels playing musical instruments. These two panels were painted by Leonardo's shop and are located in the National Gallery in London. The London *Virgin of the Rocks* shows the Virgin wearing a deeper blue **color** echoed in the atmospheric background, which is not typical of Leonardo's late work. The Baptist now has a shepherd's staff resting on his shoulder, the figures have haloes, and the angel has wings, all of which are attributes perhaps added later to clarify the identity of the figures. The main difference in these two versions, however, is that here the angel does not point across to the infant Baptist, but instead supports Christ. Although it is not clear why two versions of this painting are credited to Leonardo, it is thought that perhaps Leonardo took the first version to France, where it was sold to the royal collection after Leonardo's death, which would explain how it was seen in the Royal Collection at Fontainebleau by Cassiano dal Pozzo in 1625. The second version would have been made by his Milanese workshop to fulfill the original commission given by the Confraternity of the Immaculate Conception for their chapel in the Church of San Francesco Grande in **Milan**. This later version was sold in the 1780s to Grand Tour Scottish painter and art dealer Gavin Hamilton, who took it to London, where it was bought in 1880, for the National Gallery, which then bought the side panels for the museum in 1898.

Documents note that Leonardo received a commission for the altarpiece on 25 April 1483, from the prior of the confraternity, Bartolomeo Scorlione while his assistants, Evangelista, and his brother, **Giovanni Ambrogio de Predis**, were hired to assist Leonardo. The commission contract is known today, and it describes in detail the subject, size, and materials for the work, which was to be an elaborate multipaneled altarpiece completed for the Feast Day of the Immaculate Conception, 8 December 1483. Leonardo was initially paid 100 lire to buy materials, and then 40 lire a month, but the work dragged on past the deadline until sometime in the 1490s, when Leonardo, together with his assistant, de Predis, requested more money to cover the cost of materials, and even asked Duke **Lodovico Sforza** to intervene on their behalf. This disagreement

Leonardo da Vinci, *Virgin of the Rocks*, c. 1483–6, oil on wood transferred to canvas, 78.3 x 48 inches, Paris, Louvre Museum.

continued until 1506, when the confraternity requested that Leonardo finish the painting.

De Predis could then have painted the London version in consultation with Leonardo to fulfill the commission, since the painting is recorded as having been installed at the church in 1508. It was the London version later purchased by Gavin Hamilton. In 2005, a thorough examination of the London painting revealed pentimenti outlines of a different painting beneath the work, however, which the museum has confirmed to be done by Leonardo. Despite the fact that a definitive attribution may never be possible, these two works are the source for many copies, including one by **Bernardino Luini** in the Prado Museum in Madrid and another by **Marco d'Oggiono** in the Thuelin Collection in Paris. *See also* ANTONELLO DA MESSINA, CATHOLICISM, GEOLOGY; GAMPIETRINO, *HOLY INFANTS EMBRACING*; LANDSCAPES, LEONARDESCHI; *MADONNA OF THE YARNWINDER* (*BUCCLEUCH*), MUSEUMS, MUSIC, YÁÑEZ DE LA ALMEDINA, FERNANDO.

VITRUVIAN MAN. Leonardo's pen and ink drawing titled *Le proporzioni del corpo umano secondo Vitruvio* is more famously known as the *Vitruvian Man*. This individual drawing, done on a **light** brown sheet of paper that measures 13.6 x 10 inches, is now located in the Accademia in **Venice** (Gabinetto dei disegni e stampe, 228) and dates to about 1492. In the center of the drawing is a nude, frontally posed man, seen standing with both legs together and then both legs spread out along the lines of a circle, while his arms are shown stretched out first horizontally and then out and up, slightly above his shoulders. The man's body is located inside a square that is superimposed on a circle, so the feet and fingers reach out to the lines of both the circle and square, suggesting that the square reveals the proportions of the body at rest, while the circle measures the body in motion. The positioning of the legs and arms create an angle, and thus an equilateral triangle, which measures the movement from one point to another.

The triangle, square, and circle are the three basic geometric shapes that Leonardo considered the foundation for all types of lines and shapes. Leonardo's writing above and below the drawing explain the related ideas of ancient Roman architect **Marcus Pollio Vitruvius** (c. 80 BCE–c. 15 BCE), whose architectural treatise *De architectura* has recently been translated into Italian from **Latin** and was widely known in the literary circles of **Florence** and used by **Leon Battista Alberti** (1404–1472) in his *De re aedificatoria*, from c. 1450. Vitruvius's discussion of the ideal proportions of the human body and their relation to **architecture** inspired Leonardo's drawing and is found in Book III of his treatise. Here, Leonardo uses the human body as a microcosm that anticipates the larger measurements of the universe, where he lists Vitruvius's measurements for the hand, foot, and so forth, with the navel in the center of the symmetrical body. The proportions shift slightly as the body stretches out, but Leonardo shows that this movement can be codified in the same way as the still figure.

In this drawing, Leonardo demonstrates a clear understanding of Vitruvius's ideas on proportion, together with his own confirmation of these ideas through careful observation. For example, he noted that once the body moves, the navel shifts downward. Thus, the square and the circle have different center points. This is not the first proportional drawing of the nude male figure, however, as variations are found in the architectural treatise of Sienese architect **Francesco di Giorgio Martini** from the 1470s, and in Giacomo Andrea da Ferrara's *Vitruvian Man* (Ferrara, Biblioteca Ariostea, cart. Sec. XVI, Fol. Figurato, Classe II, N. 176, fol. 78v), but Leonardo's drawing is the first to make such highly accurate observations. **Luca Pacioli** noted that Giacomo Andrea was a close friend of Leonardo's, and Leonardo himself wrote that he had dinner with Giacomo Andrea in 1490. Like Leonardo's more famous work, Giacomo Andrea's version shows a frontally posed nude man standing with his legs together, inscribed in both a circle and a square. His arms reach up to form a triangle measured from the navel of the figure. Unlike Leonardo's version, Giacomo's does not suggest movement in the legs and arms, so Leonardo's

work resolved several issues of proportion and movement not found in other examples. *See also* BROWN, DAN; CLASSICISM; GEOMETRY MATHEMATICS; NOTEBOOKS.

Leonardo da Vinci, *Vitruvian Man*, c. 1492, ink and wash on paper, 13.6 x 10 inches, Venice, Accademia.

VITRUVIUS, MARCUS POLLIO (c. 80–c. 15 BCE). Marcus Pollio Vitruvius, known as Vitruvius, was an ancient Roman engineer whose treatise on architecture, *De architectura*, from the 1st century BCE, was the sole surviving architectural manual from antiquity and had an enormous influence on the **Renaissance** revival of **classicism**. Little is known of his life, including the veracity of his first and middle name, but Vitruvius explained in his treatise that he first served in the Roman army, and there he learned how to operate complex military machinery and became a military architect and perhaps served in North Africa, Hispania (modern Spain), and Gaul in Northern Europe, and his descriptions of battle locations and tactics are invaluable historical information. As a military architect, the only building attributed to him is a basilica in the small town of Fano, near modern-day Urbino in the Marche region of Italy, which is perhaps beneath the Cathedral of Fano.

Vitruvius's treatise, translated in the *Ten Books of Architecture*, is a volume of 10 chapters on different types of buildings, construction practices, and aesthetics. Written in **Latin**, it was rediscovered in 1414, by Florentine scholar Poggio Bracciolini (1380–1459), and **Leon Battista Alberti** incorporated Vitruvius's teachings in his own treatise written in Latin, *De re aedificatoria*, written in Rome in about 1450, and both books were enormously influential on Leonardo. Both books were also widely published with the advent of the printing press later in the century and laid the foundation for subsequent revivals of classical architecture, notably the neoclassical buildings constructed in the United States in the late 1700s and early 1800s. In the treatise, Vitruvius described many different machines needed for construction, including hoisting machines, **cranes**, pulley systems, and Archimedes's screw, which Leonardo employed in many of his **inventions**. For Vitruvius, the screw was primarily used for moving water. His descriptions of the Roman aqueducts and water technology would have also been a major influence on Leonardo, as well as his discussions of catapults, **cannons**, and other military equipment. The surveying tools used by Leonardo's assistants while mapping the central region of Italy for **Cesare Borgia** were also first described by Vitruvius.

Vitruvius was primarily interested in the functional aspect of buildings and even sought to invent a type of central heating system for Roman apartments, however, in one chapter of his treatise, he also described different types of buildings, their appropriate layout, and how they should be articulated. In his theater designs, for example, he took acoustics into account in his stage designs. He also described how an architect must be well

read and widely educated, which influenced Renaissance notions about the emerging architectural career in the 1400s. In general, Vitruvius considered the proportions of architecture to derive from the human body, and Leonardo's ***Vitruvian Man*** expresses those ideas, where a circle and square are used to measure the human body. According to Vitruvius, columns also derive from the same proportional system, and the column orders, including the Doric, Ionic, and Corinthian, were fundamental to his aesthetic ideals. He also described a successful building as having *firmitas*, or strength, *utilitas*, or utility, and *venustas*, or beauty, in equal parts. *See also* ADDING MACHINE, ANATOMY; ARCHITECTURE, BRAMANTE, DONATO, BROWN, DAN, BRUNELLESCHI, FILIPPO; ENGINEERING; MANTUA; MATHEMATICS; PACIOLI, LUCA; SANGALLO, GIULIANO DA.

W

WAAGEN, GUSTAV FRIEDRICH (1794–1868). In 1832, German art historian Gustav Waagen was appointed director of the new Berlin Museum, where he focused his work on forming their painting collection. He traveled extensively and honed his skills as a connoisseur, and in 1844, he was hired at Berlin University to hold the first university position in art history. From there, he worked as a museum advisor, where he helped authenticate, name, categorize, and organize the imperial collection of **paintings** in preparation for their display. His notes on both public and private collections in Europe contain invaluable information on collection provenance, as well as early stylistic analyses. As an advisor to the British Museum in London and the Hermitage collection in St. Petersburg, he published *Treasures of Art in Great Britain*, in three volumes, in 1854. It was translated into English by British art critic Lady **Elizabeth Eastlake**.

Waagen is credited with restricting Leonardo's oeuvre, which in the early years of modern connoisseurship had expanded to include numerous paintings by Leonardo's students and followers, called the **Leonardeschi**. By sorting these works out of Leonardo's career and reattributing a famous Leonardo painting to **Bernardino Luini**, Leonardo's late career became clearer. Then he turned his attention to clarifying Leonardo's early work based on the newly attributed angel in his teacher, **Andrea del Verrocchio's**, *Baptism of Christ*. Contemporary German art historian **Karl Eduard von Liphart**, who was also part of the German colony of art historians and enthusiasts in **Florence**, also turned his attention to Leonardo's early career, where he was able to make a strong case for reattributing the newly discovered ***Annunciation*** from **Domenico Ghirlandaio** to Leonardo. *See also* BODE, WILHELM VON.

WATER STUDIES. Leonardo was fascinated with water and its movement, and planned to write a treatise on water. His sketches of flowing water, falling water, and water moving past obstacles spanned his entire career, and his interest in water informed both the landscape views of his **paintings** and his **engineering** studies of canals, dams, and lakes. Leonardo observed many similarities between the human body and nature, the flow of water and blood, as well as the patterns of water movement and the growth of plants. One particular annotated sketch from about 1507 shows three different views of water flowing past obstacles (11.4 x 8 in., ink on paper, Windsor, Royal Library). At the top of the page, the water flows around a rectangular book-like object set perpendicular to the water flow. Next, the object is set angled upward but parallel to the water flow. Finally, the bottom image shows water gushing out of a drain and falling down, where it hits a body of water, churning up and mixing with the pool to create dramatic swirling turbulence and waves that resemble curling hair of the patterns of wind. At the bottom of the page, Leonardo wrote his observations on the behavior of water in these three different situations. Another drawing, *Deluge over a City*, from c. 1517 (6.4 x 8.2 in., chalk on paper, Windsor, Royal Library), depicts a powerful storm that

soaks a town in water and wind, revealing the destructive potential of water.

Leonardo knew that one could only understand the movement of nature if one could accurately observe and describe it. He was also the first person to describe how clouds are formed by water vapor rising into the air and how rain falls from the clouds, which he saw while hiking north of **Milan** along the Lago Maggiore. While many people since antiquity had made this connection between clouds and rain, Leonardo tried to measure the density of vapor at its boiling point and create a small steam engine to emit vapor. He also argued that fossilize shells found inland and on mountains cannot be explained by the biblical Great Flood, because the water would have had no place to move away to in a manner to leave shells behind. Moreover, Leonardo was the first artist to observe the principle of surface tension, which he described as tenacity and cohesion where a drop of water clings to the larger body of water, elongating until it separates and breaks free due to its weight. Leonardo studied both fluids at rest, called **hydrostatics**, and fluids in motion, called **hydrodynamics**. According to Leonardo, water never rests, and his observations formed the basis for the discipline of fluid dynamics. *See also* AERODYNAMICS, CHEMISTRY; GEOLOGY; ICHNOLOGY; INVENTIONS, LANDSCAPES; NOTEBOOKS, *PARIS MANUSCRIPTS*; TOPOLOGY, *WINDSOR FOLIOS*.

WEAPONS. *See* AUTOMATON, BOATS; BRIDGES; CANNONS, DIVING SUIT, SCYTHED CHARIOT, 33-BARREL ORGAN, TANK; WHEEL-LOCK MUSKET.

WHEEL LOCK MUSKET. On fol. 18v of Leonardo's ***Madrid Codex I*** is a design for a hand-held rifle with an automatic match-lock, or wheel-lock with a spring mechanism that would release when a trigger is pulled, causing a rotating wheel called a flywheel to spin and create sparks to strike the flint, which was iron pyrite. This would ignite the gun powder, causing an explosive force to propel a bullet out of the gun chamber. This was the first device designed to fire guns mechanically. A more detailed drawing is found in the ***Codex Atlanticus***, fols. 56v–r, which shows either the mainspring resembling a screw mechanism, or a coil spring, used for more effective cocking mechanisms. The advantage of this system is that the wheel-lock ignites the powder rather than the traditional use of a burning cord for ignition and is therefore much safer and easier since the match cords had to be kept dry and continually loaded. This also makes the musket more portable, as smaller versions were soon designed, as well as the hand-held pistol, all without the cumbersome match cord.

Although this device is attributed to an unknown German engineer and dated to 1505, many scholars think Leonardo was first to design the wheel-lock mechanism. Leonardo designed many other instruments for warfare, including a giant **crossbow**, an armored military **tank**, and a **33-barrel organ**, which was the first machine gun. While many of these concepts never came to fruition, Leonardo's wheel-lock mechanism and his new gunpowder recipes were put into practice during his lifetime. *See also* AUTOMATON; BOATS; BRIDGES; CANNONS; ENGINEERING; INVENTIONS.

WINDSOR FOLIOS. The Royal Collection Trust of the United Kingdom conserves art at several locations, including Windsor Castle in London, which holds about 600 **drawings** by Leonardo that span Leonardo's life and cover diverse subjects, including **anatomy** and **animal studies**, **caricatures**, and maps. These drawings vary in size, are unbound, and span Leonardo's career, from 1478–1518. They are done in pen and ink, chalk, pencil, and watercolor, and were originally bound in a volume that was likely purchased in the 1600s, by Charles II of England. His most famous drawings in the collection include a *Study of Cats, Lions, and a Dragon* (c. 1513–1516), *The Deluge* (c. 1517–1518), and *Study for the Head of St. Anne* (c. 1510–1515). *See also ANNUNCIATION*; BOTANICAL STUDIES, CANNONS; CARTOGRAPHY; CLARK, KENNETH MACKENZIE; *CODEX FORSTER*; CRANES; ENGINEERING, HYDRAULICS; LANDSCAPES; *LUCAN PORTRAIT OF LEONARDO*; MUSEUMS, NOTEBOOKS;

PEDRETTI, CARLO, *VITRUVIAN MAN*; WATER STUDIES, WORLD MAP.

WORLD MAP. Leonardo's world map is an octant projection composed of eight spherical, or Reuleaux, triangles curved to fit on the surface of a sphere that was found in a collection of Leonardo's drawings in the Royal Library at Windsor. They are arranged like two four-leaf clovers that can fold to cover the surface of a sphere without overlapping, thereby reducing the spatial distortion that occurs when flattening a spherical image. The earth poles are at the center of each clover, while the side that is opposite the center runs along the equator and while the remaining two sides come together to form the meridians. This type of design was first devised by Leonardo in 1508, in a rough sketch found in his ***Codex Atlanticus***, together with seven other globe sketches, one of which is Ptolemy's conical planisphere, and this sketch is considered the basis for Leonardo's world map from 1514.

While some scholars dispute the attribution of one or both of these drawings to Leonardo, most consider both drawings to have at least been done in the close circle of Leonardo. The map is also one of the earliest to label America, after the German cartographers Matthias Ringmann (1482–1511) and Martin Waldseemüller (c. 1470–1520) first devised the name, a variant on Amerigo, which appears on their 1507 map the *Universalis Cosmographia*. Florentine explorer Amerigo Vespucci's (1454–1512) travel reports from between 1502–1506, which were sent to Lorenzo di Pierfrancesco de' **Medici** and later **Piero Soderini**, were widely known, and Leonardo would most likely have had access to them during those same years he spent in **Florence**. Leonardo's world map also shows the Arctic Ocean and Antarctica at roughly the correct size for the first time. Florida, however, is drawn as an island rather than a peninsula but is correctly located near Cuba. *See also* CARTOGRAPHY, *WINDSOR FOLIOS*.

Y

YÁÑEZ DE LA ALMEDINA, FERNANDO (c. 1475–1536). This Spanish painter of Moorish heritage studied painting in Italy, where he was introduced to the work of Leonardo. Leonardo's heightened realism and soft **chiaroscuro** influenced many Flemish and Spanish artists, and Almedina is credited with introducing Leonardo's style to Spain upon his return to Valencia from Italy. Little is known of his life, but he is documented as having traveled to **Florence** with Spanish painter **Hernando de los Llanos** to assist Leonardo on his unfinished ***Battle of Anghiari*** wall mural. His *Virgin and Child with the Infant John the Baptist*, c. 1505, **oil** on wood (Washington, D.C., National Gallery), reflects both the Florentine popularity of the seated Madonna and Child in a landscape background and the style of Leonardo's Second Florentine Period of 1500–1506, when Leonardo introduced the softly modeled Virgin turning in space to clutch her squirming Christ Child while holding her opposite palm down in front of her. This unique gesture appears in Leonardo's ***Virgin of the Rocks*** from Leonardo's First Milanese Period from 1482–1499. *See also* LANDSCAPES; LEONARDESCHI.

Z

ZOOLOGY. *See* ANIMAL STUDIES.

Bibliography

INTRODUCTION

This bibliography provides further information on Leonardo da Vinci beginning with the earliest primary sources, including an anonymous biographer called the "Anonimo Gaddiano," who wrote about Leonardo in the 1530s, and Giorgio Vasari (1511–1574), who discussed Leonardo in his *Lives of the Most Excellent Painters, Sculptors, and Architects*, first published in 1550. Art historical studies of Leonardo's career began in earnest in the early 1800s, and Carlo Amoretti's biography of Leonardo from 1804 was the first to use documentation. In 1810, Giuseppe Bossi's monograph on Leonardo's *Last Supper* presented the first examination of Leonardo as an artist, and the book received a favorable review from Johann Wolfgang von Goethe (1749–1832), who is credited with popularizing Leonardo's work in Germany and England. Giorgio Vasari's *Lives* has been widely published since the Renaissance, and his preference for Florentine art was continued by art collectors and historians during the Grand Tour, when wealthy Europeans flocked to Florence to study and collect art from the mid-1600s through the 1800s. Thus, when wealthy art collector Karl Eduard von Liphart moved from Estonia to Florence in 1862, he joined a thriving community of artists, art historians, and art collectors that was beginning the earliest academic studies of Leonardo's career. Liphart is credited with identifying Leonardo's *Annunciation* while purchasing a collection of Italian Renaissance paintings.

During this same time, Italian doctor and art critic Giovanni Morelli developed a method of connoisseurship, explained in his *Die Werke Italienischer Meister* from 1880, where he proposed that authorship can be detected in small or unconscious traces. The Morellian method was used by European scholars and collectors to identify the many paintings newly discovered during the 1800s, and this led to numerous French, German, and Italian studies on Leonardo published in the last two decades of the 1800s, including Paul Müller-Walde's *Leonardo da Vinci, Lebensskizze und Forsche* (1889), Gabriel Séailles's *Léonard de Vinci, L'artiste et le savant* (1892), Eugene Müntz's *Léonard de Vinci, L'artiste, le penseur, le savant* (1899), and Walter Pater's chapter on Leonardo in *The Renaissance* from 1893. More biographies were written in the early 1900s, including those by Edmondo Solmi (1900), Waldemar von Seidlitz (1909), and Wilhem Suida (1929). Kenneth Clark wrote the first comprehensive English-language biography, published in 1939, which was followed by Ludwig Heydenreich's monograph, translated into English in 1953. Malaguzzi Valeri's 1915 study, in Italian, was the first to contextualize Leonardo's career in the court of Lodovico Sforza in Milan. Meanwhile, Leonardo's art was becoming popular in the United States by the early 1900s, and Bernard Berenson's authentications led to the establishment of numerous Italian Renaissance art collections in American museums. In his *The Study and Criticism of Italian Art*, from 1916, Berenson reassessed Leonardo's oeuvre with an eye toward clarifying attributions.

While many scholars sought to piece together Leonardo's painting career, German scholar Jean Paul Richter focused on gathering and transcribing Leonardo's annotated sketches, many of which were almost illegible, to explore Leonardo's thoughts. Richter's first publication, from 1883, was one of the earliest English-language books on Leonardo's drawings, written after Richter moved to London. In 1938, Edward McCurdy, in his *The Notebooks of Leonardo da Vinci*, sought to balance Richter's emphasis on Leonardo's artistic ideas with an examination of his scientific studies. Scholarship on Leonardo's notebooks continued throughout the 20th century and includes Girolamo Calvi's important chronological study of Leonardo's notebooks from 1925, Kenneth Clark's catalog of his drawings from 1935, and Carlo Pedretti's work at Windsor Castle from 1957. Arthur Popham's 1946 study of Leonardo's drawings was the most complete to date, while Richter's book was revised and republished by his daughter, Irma Richter, and remains the primary source today. Today, online resources are making Leonardo's notebooks more widely available in the form of digital facsimiles.

Later 20th-century research in the English language has been dominated by Carlo Pedretti, an Italian-born scholar who was Armand Hammer Chair in Leonardo Studies at the University of California, and Martin Kemp, emeritus professor at the University of Oxford, both of whom devoted their entire careers to the study of Leonardo da Vinci and have written hundreds of publications on him. Numerous contemporary scholars have also worked to assemble a complete list of Leonardo's oeuvre, including Pietro Marani, who published a complete catalog of Leonardo's paintings in Italian in 1999, which was translated into English in 2000, and in 2015, Frank Zöllner and Johannes Nathan published a complete catalogue of Leonardo's paintings and drawings in a thick tome that is the most comprehensive examination of Leonardo's entire output to date.

Leonardo has enjoyed a recent surge in popularity, with paperback books and movies that feature him, notably Dan Brown's *The Da Vinci Code* from 2003, a best-selling mystery and movie that romanticizes Leonardo's impact on world history by focusing on his number symbolism and scientific interests. More recent books on Leonardo have also become best sellers, including Walter Isaacson's *Leonardo da Vinci*, a biography published in 2017, and books that capitalize on Leonardo's genius, for example, Michael Gelb's *How to Think Like Leonardo da Vinci*, from 2000. *The Science of Leonardo* is another best seller, this one written by physicist Fritjof Capra in 2007.

In late 2017, a panel painting of the *Salvator Mundi*, attributed to Leonardo, sold for a record sum of $450 million. This unprecedented amount of money has further elevated the already high monetary value of Leonardo's artwork, which ensures that, despite the extensive amount of literature already written about Leonardo, more research is needed on such hotly debated new attributions. This bibliography is therefore not exhaustive, but preference is given to English-language sources, including both popular and scholarly texts, and monographs and exhibition catalogues, with some articles and important writings in Italian, French, and German.

Ackerman, James. "Science and Art in the Work of Leonardo." In *Leonardo's Legacy. An International Symposium*, ed. Charles D. O'Malley, pp. 205–25. Berkeley. University of California Press, 1969.

Ahl, Diane Cole. *Leonardo da Vinci's Sforza Monument Horse: The Art and the Engineering*. Bethlehem, Pa.: Lehigh University Press, 1995.

Alexander, David "Leonardo da Vinci and Fluvial Geomorphology." *American Journal of Science* 282, no. 6 (1982): 735–55.

Ames Lewis, Francis. *Isabella and Leonardo. The Artistic Relationship between Isabella d'Este and Leonardo da Vinci, 1500–1506*. New Haven, Conn.: Yale University Press, 2012.

Amoretti, Carlo. *Memorie storiche su la vita gli studi e le opera di Leonardo da Vinci*. Milan: Tipografia di Giusti, 1804.

"Anonimo." In *Codice Magliabecchiano*, ed. Karl Frey. Berlin. G. Grotesche Verlagsbuchhandlung, 1892.

Aquino, Lucia. *Leonardo da Vinci.* Milan: Skira, 2008.

Arasse, Daniel. *Leonardo da Vinci.* New York: Konecky and Konecky, 2006.

———. *Leonardo da Vinci. The Rhythm of the World.* New York: Konecky and Konecky, 1998.

Arrighi, Vanna, Anna Bellinazzi, and Edoardo Villata, eds. *Leonardo da Vinci: La vera imagine, documenti e testimonianze sulla vita e sull'opera.* Florence. Archivio di Stato, 2005.

Atalay, Bülent. *Math and the Mona Lisa: The Art and Science of Leonardo da Vinci.* Washington, D.C.. Smithsonian Books, 2004.

Azzolini, Monica. "In Praise of Art: Text and Context of Leonardo's *Paragone* and Its Critique of the Arts and Science." *Renaissance Studies* 19, no. 4 (September 2005): 487–510.

Bambach, Carmen C. "Leonardo and Drapery Studies on 'tela sottilissima di lino.'" *Apollo* 160, no. 503 (January 2004). 44–55.

———. "Leonardo's Notes on Pastel Drawing." *Mitteilungen des Kunsthistorisches Institutes in Florenz* 52, nos. 2/3 (2008): 177–204.

———, ed. *Leonardo da Vinci. Master Draftsman.* New Haven, Conn. Yale University Press, 2003.

Baucon, Andrea. "Leonardo da Vinci, the Founding Father of Ichnology," *Palaios* 25, no. 6 (2010). 361–67.

Bayer, Andrea, ed. *Painters of Reality. The Legacy of Leonardo and Caravaggio in Lombardy* Exh cat. New York Metropolitan Museum of Art, 2004.

Beatis, Antonio de'. *Die Reise des Kardinals Luigi d'Aragona.* Ed. Ludwig Pastor. Freiburg im Breisgau: Dogma, 1905.

Beck, James. "Ser Piero da Vinci and his Son Leonardo." *Source: Notes in the History of Art* 5, no. 1 (Fall 1985). 29–32.

Bell, Janis. "Leonardo's 'prospettiva delle ombre': Another Branch of Nonlinear Perspective." In *Leonardo da Vinci and Optics,* ed. Francesca Fiorani and Alessandro Nova, pp. 79–111. Florence. Kunsthistorisches Institut in Florenz, 2013.

Belt, Elmer. *Leonardo the Anatomist.* Lawrence: University of Kansas Press, 1955.

Beltrami, Luca. *Documenti e memorie riguardanti la vita e le opera di Leonardo da Vinci.* Milan. Fratelli Treves, 1919.

Berenson, Bernard. *The Drawing of the Florentine Painters, Classified, Criticized, and Studied as Documents in the History and Appreciation of Tuscan Art.* 2 vols. London: J Murray, 1903.

———. *The Study and Criticism of Italian Art.* London: Bell, 1916

Billingsley, Paula. *Leonardo e Venezia.* Milan: Bompiani, 1992

Bode, Wilhelm von. *Florentiner Bildhauer der Renaissance.* Berlin: B Cassirer, 1902.

———. *Studien über Leonardo da Vinci.* Berlin. Grote'sche Verlagsbuchhandlung, 1921.

Bodmer, Heinrich, ed. *Leonardo. Des Meisters Gemälde und Zeichnungen.* Stuttgart: Deutsche Verlags, 1931.

Bora, Giulio, et al. *I Leonardeschi L'eredità di Leonardo in Lombardia.* Milan: Skira, 1998

Bossi, Giuseppe. *Del "Cenacolo" di Leonardo da Vinci.* Milan: Della Stamperia Reale, 1810.

Bramly, Serge *Leonardo: The Artist and the Man.* Trans. Sian Reynolds. London: Penguin, 1995.

———. *Leonardo: Discovering the Life of Leonardo da Vinci.* New York: HarperCollins, 1991.

Britton, Piers Dominic. "The Signs of Faces: Leonardo on Physiognomic Science and the 'Four Universal States of Man'" *Renaissance Studies* 16 (2002). 143–62.

Brown, Dan *The Da Vinci Code A Novel.* New York: Doubleday, 2003.

Brown, David Alan. *Leonardo da Vinci: Origins of a Genius.* New Haven, Conn.: Yale University Press, 1998

———. *Virtue and Beauty: Leonardo's Ginevra de' Benci and Renaissance Portraits of Women.* Exh. cat. Washington, D.C.. National Gallery of Art, 2001.

Brown, David Alan, and Maro Carminati. *The Legacy of Leonardo: Painters in Lombardy, 1490–1530.* Milan: Skira, 1999.

Bush, Virginia L. "Leonardo's Sforza Monument and Cinquecento Sculpture." *Arte Lombarda* 50 (1978): 47–68.

Butterfield, Andrew. "Leonardo da Vinci. Master Draftsman." *Apollo* 158 (2003): 50–51.

Calvi, Gerolamo. *I manoscritti di Leonardo da Vinci del punto di vista cronologico, storico e biografico.* Bologna: Nicola Zanichelli, 1925.

Cantile, Andrea, ed. *Leonardo: The Genius and the Cartographer: The Representation of Land in Science and Art.* Florence. Istituto Geografico Militare, 2003.

Capati, Massimiliano. *Leonardo: A Life through Paintings.* Florence: Mandragora, 2009.

Capra, Fritjof. *Learning from Leonardo. Decoding the Notebooks of a Genius.* Oakland, Calif : Berrett-Koehler, 2013.

———. *The Science of Leonardo: Inside the Mind of the Great Genius of the Renaissance.* New York. Anchor Books, 2007.

Castelfranco, Giorgio. *Studi Vinciani.* Rome: De Luca, 1966.

A Catalogue of the Drawings of Leonardo da Vinci at Windsor Castle, 2nd ed. 2 vols. Cambridge, U.K.: Cambridge University Press, 1935. Revised by Carlo Pedretti. London: Phaidon, 1968–1969.

Chastel, Andre. *The Genius of Leonardo da Vinci.* New York. Orion, 1961.

———. *Leonardo da Vini. Studi e ricerche 1952–1990.* Trans. Giancarlo Coccioli. Turin: Einaudi, 1995.

———, ed. *Leonardo da Vinci. Sämtliche Gemälde und die Schriften zur Malerei.* Munich. Schirmer/Mosel, 1990.

Clagett, Marshall. "Leonardo da Vinci: Mechanics." In *Leonardo's Science and Technology,* ed. Claire Farago, pp. 215–34. New York: Garland, 1999.

Clark, Kenneth. *A Catalogue of the Drawings of Leonardo da Vinci in the Collection of Her Majesty the Queen at Windsor Castle.* Cambridge, U.K.: Cambridge University Press, 1935.

———. *Leonardo da Vinci.* London. Phaidon, 1954.

———. *Leonardo da Vinci. An Account of His Development as an Artist.* Cambridge, U.K.: Cambridge University Press, 1939.

Clark, Kenneth, and Carlo Pedretti. *The Drawings of Leonardo da Vinci in the Collection of Her Majesty the Queen at Windsor Castle.* New York. Phaidon, 1968.

Clark, Kenneth, and Martin Kemp. *Leonardo da Vinci,* rev. ed. London: Penguin, 1989.

Clayton, Martin, and Ronald Philo. *Leonardo da Vinci, Anatomist.* London: Royal Collection Publications, 2014.

———. *Leonardo da Vinci. The Mechanics of Man.* Exh. cat. London: Royal Collection Publications, 2010.

Cleave, Claire van *Leonardo da Vinci and His Circle.* Exh. cat. London: British Museum, 2008.

Cole, Michael Wayne. *Leonardo, Michelangelo, and the Art of the Figure.* New Haven, Conn.: Yale University Press, 2014.

Collins, Bradley. *Leonardo, Psychoanalysis, and Art History. A Critical Study of Psychobiographical Approaches to Leonardo da Vinci.* Evanston, Ill.. Northwestern University Press, 1997.

Cooper, Margaret Rice. *The Inventions of Leonardo da Vinci.* New York: Macmillan, 1965.

da Vinci, Leonardo. *Trattato della Pittura di Leonardo da Vinci.* Preface by Angelo Borzelli. Lanciano: Carabba, 1914.

de Rossi, Giovanni Gherardo, and Guglielmo Manzi, eds. *Trattato della Pittura di Lionardo da Vinci tratto da un codice della Biblioteca Vaticana.* Rome: Stamperia de Romanis, 1817.

Delieuvin, Vincent, ed. *Saint Anne. Leonardo da Vinci's Ultimate Masterpiece.* Milan: Officina Libraria, 2012.

Dibner, Bern "Leonardo Prophet of Automation." In *Leonardo's Legacy. An International Symposium,* ed. Charles D. O'Malley, pp. 101–23. Berkeley: University of California Press, 1969.

———. *Leonardo da Vinci. Machines and Weaponry.* Norwalk, Conn.: Burndy Library, 1974.

Duvernoy, Sylvie. *Nexus Network Journal. Leonardo da Vinci. Architecture and Mathematics.* Basel: Birkhäuser Basel, 2008.

Edsel, Robert M. *Rescuing Da Vinci: Hitler and the Nazis Stole Europe's Greatest Art—America and Her Allies Recovered It.* New York: Laurel, 2006.

Emboden, William A. *Leonardo da Vinci on Plants and Gardens.* Portland, Ore.: Dioscorides Press, 1987.

———. "A Renaissance Botanist: Leonardo da Vinci." *Hortulus aliquando* I (1975–1976): 13–29.

Fahy, Everett. *The Legacy of Leonardo. Italian Renaissance Paintings from Leningrad.* Exh. cat. Washington, D.C.. National Gallery of Art, 1979.

Farago, Claire. *Leonardo da Vinci's 'Paragone'. A Critical Interpretation with a New Edition of the Text in the Codex Urbinas.* Leiden: Brill, 1992.

———, ed. *Leonardo da Vinci. Selected Scholarship.* 5 vols. New York. Garland, 1999.

———, ed. *Re-reading Leonardo: The Treatise on Painting across Europe, 1550–1900.* Abingdon-on-Thames: Routledge, 2017.

Feinberg, Larry J. *The Young Leonardo. Art and Life in 15th-Century Florence.* Cambridge, U.K.: Cambridge University Press, 2011.

Fiori, Maria Teresa, ed. *Leonardeschi in Lombardia.* Exh. cat. Milan: Amilcare Pizzi, 1982.

Fletcher, Jennifer. "Bernardo Bembo and Leonardo's Portrait of Ginevra de' Benci." *Burlington Magazine* 131 (1989): 811–16.

Foley, Vernard, et al. "Leonardo, the Wheel Lock, and the Milling Process." *Technology and Culture* 24, no. 3 (July 1983): 399–427.

Fresne, Raffaele Du'. *Trattato della pittura di Leonardo da Vinci.* Paris: Giacomo Langlois, 1651.

Freud, Sigmund *Leonardo da Vinci: A Memory of his Childhood.* London: Routledge, 1957. From the original *Eine Kindheitserinnerung des Leonardo da Vinci.* Vienna: F. Deuticke, 1910.

Frey, Karl. *Il Codice magliabechiano, cl. xvii. 17, contenente Notizie sopra l'arte degli antichi e quella de' Fiorentini da Cimabue a Michelangelo Buonarroti, scritte da Anonimo Fiorentino.* Berlin: G. Grote'sche Verlagsbuchhandlung, 1892.

Galluzzi, Paolo. *Renaissance Engineers. From Brunelleschi to Leonardo da Vinci.* Florence: Giunti Barbera, 2001.

Galluzzi, Paolo, and Jean Guillaume, eds. *Leonardo de Vinci: Ingénieur et architect.* Montréal. Musée des Beaux Arts, 1987.

Gelb, Michael J. *How to Think Like Leonardo da Vinci. Seven Steps to Genius Every Day.* New York: Dell, 2000.

Gibbs-Smith, Charles Harvard, and Gareth Rees. *The Inventions of Leonardo da Vinci.* London: Peerage, 1978, 1985.

Giovio, Paolo. "The Life of Leonardo da Vinci." Written c. 1527, published by Girolamo Tiraboschi, et al. *Storia della Letteratura Italiana.* VII, Venice: A. Cesare, A. Rosa, 1796.

Goffen, Rona. *Renaissance Rivals. Michelangelo, Leonardo, Raphael, Titian.* New Haven, Conn.: Yale University Press, 2002.

Goldscheider, Ludwig. *Leonardo da Vinci.* London: Phaidon, 1964.

———. *Leonardo da Vinci: Landscape and Plants.* London: Phaidon, 1952.

Goldstein, Thomas. *Dawn of Modern Science. From the Arabs to Leonardo da Vinci.* Boston. Houghton Mifflin, 1980.

Gombrich, Ernst H. "Leonardo's Method of Working Out Compositions." In *Norm and Form: Studies in the Art of the Renaissance,* pp. 58–63. London: Phaidon, 1966.

———. "Renaissance Theory and the Development of Landscape Painting." *Gazette des Beaux-Arts* 41 (1953): 335–60.

Gould, Cecil. *Leonardo: The Artist and the Non-artist.* Boston. Weidenfeld and Nicolson, 1975.

Gould, Stephen Jay. *Leonardo's Mountain of Clams and the Diet of Worms.* New York: Harmony Books, 1998.

Guillaume, Jean. "Leonardo da Vinci et l'architecture français, Le problème de Chambord." *Revue de l'Art* 25 (1974): 71–84.

Hales, Dianne R. *Mona Lisa: A Life Discovered.* New York: Simon and Schuster, 2014.

Hart, Ivor B. *The Mechanical Investigations of Leonardo da Vinci.* Westport, Conn.: Greenwood, 1963, 1982.

Heydenreich, Ludwig H *Leonardo da Vinci.* 2 vols. New York. Macmillan, 1954.

———. "Leonardo da Vinci, Architect of Francis I." *Burlington Magazine* 94, no. 595 (October 1952): 277–85.

———. "Qui è la veduta: Über einige Landschaftzeichnungen Leonardo da Vincis im Madrider Skizzenbuch (Cod. 8936)." In *Studies in Late Medieval and Renaissance Painting in Honor of Millard Meiss*, vol. 1, ed. Millard Meiss, Irving Lavin, and John Plummer, pp. 241–48. New York: New York University Press, 1977.

Hoffman, Volker. "Leonardo Ausmalung der Sala delle Asse im Castello Sforzesco." *Mitteilungen des Kunsthistorischen Institutes in Florenz* I (1972): 51–62.

Holly, Michael Ann. "Writing Leonardo Backwards." In *Past Looking: Historical Imagination and the Rhetoric of the Image*, 112–48. Ithaca, N.Y.: Cornell University Press, 1996.

Holmes, Charles J. "Leonardo da Vinci." *Proceedings of the British Academy* 9 (1924): 53–78

Horne, Herbert, trans. *The Life of Leonardo da Vinci by Giorgio Vasari*. London: At the Sign of the Unicorn, 1902.

I Leonardeschi. Da Foppa a Giampietro: dipinti dall'Ermitage di San Pietro Burgo e dai Musei Civici di Pavia. Exh. cat. Milan: Skira, 2011.

Isaacson, Walter. *Leonardo da Vinci*. New York: Simon and Schuster, 2017.

Jameson, Anna Brownwell. "Lionardo da Vinci." In *Memoirs of Early Italian Painters, and the Profess of Painting in Italy, Cimabue to Bassano*, rev. ed., pp. 162–80. London: John and Murray, 1868.

Keele, Kenneth D. *Leonardo da Vinci on Movement of the Hearth and Blood*. Philadelphia, Pa.: Lippincott, 1952.

———. *Leonardo da Vinci's Elements of Science of Man*. New York: Harcourt Brace Jovanovich, 1983.

———. "Leonardo's Influence on Renaissance Anatomy." *Medical History* 8, no. 4 (October 1964): 360–70.

Keele, Kenneth D., and Carlo Pedretti. *Leonardo da Vinci. Corpus of the Anatomical Studies at Windsor Castle*. London: Johnson Reprint Company, 1979–1980.

Kemp, Martin. *Leonardo*. Oxford, U.K.: Oxford University Press, 2004.

———. *Leonardo*, rev. ed. Oxford, U.K.: Oxford University Press, 2011.

———. *Leonardo da Vinci: Experience, Experiment, and Design*. Exh. cat. London: Victoria and Albert Museum, 2009.

——— *Leonardo da Vinci: The Marvelous Works of Nature and Man*. Cambridge, Mass.: Harvard University Press, 1981, 2006.

———. "Leonardo da Vinci: Science and the Poetic Impulse." *Journal of the Royal Society of Arts* 133, no. 5,343 (February 1985): 196–214

———. *The Science of Art: Optical Themes in Western Art from Brunelleschi to Seurat*. New Haven: Yale University Press, 1992.

———. *Structural Intuitions: Seeing Shapes in Art and Science*. Charlottesville: University of Virginia Press, 2016

Kemp, Martin, and Giuseppe Pallanti. *Mona Lisa: The People and the Painting*. Oxford, U.K.: Oxford University Press, 2017.

Kemp, Martin, and Margaret Walker, eds. *Leonardo on Painting. An Anthology of Writings*. New Haven, Conn.: Yale University Press, 1989.

Kemp, Martin, and Marina Wallace. *Spectacular Bodies: The Art and Science of the Human Body from Leonardo to Now*. Exh. cat. London: Hayward Gallery, Los Angeles: University of California Press, 2000.

Kemp, Martin, and Pascal Cotte. *La Bella Principessa*. London: Hodder and Stoughton, 2010

Kemp, Martin, et al. *Leonardo da Vinci and the Art of Sculpture*. Ed. Gary Radke. New Haven, Conn.: Yale University Press, 2009.

King, Ross. *Leonardo and the Last Supper*. New York: Walker and Co., 2012

Klein, Stefan. *Leonardo's Legacy: How da Vinci Reimagined the World*. Trans. Shelley Frisch. Boston: Da Capo, 2011.

Klein, Stefan, and Shelley Frisch. *Leonardo's Legacy: How da Vinci Reimagined the World*. Boston: Da Capo, 2011.

Knapp, Fritz. *Leonardo da Vinci*. Leipzig: Verlag von Velhagen and Klasing, 1938.

Landrus, Matthew. "Mathematica. and Proportion Theories in the Work of Leonardo da Vinci and Contemporary Artist/Engineers at the Turn of the 16th Century."

In *Visual Culture and Mathematics in the Early Modern Period*, ed. Ingrid Alexander-Skipnes, pp. 52–68. New York: Routledge, 2017.

Laurenza, Domenico. "Leonardo nella Roma di Leone X." In *XLIII Lettura Vinciana*. Vinci: Biblioteca Leonardiana, 2003.

———. *Leonardo on Flight*. Florence: Giunti Barbèra, 2004.

Leader, Anne. "'In the Tomb of Ser Piero'. Death and Burial in the Family of Leonardo da Vinci." *Renaissance Studies* 31, no 3 (June 2017): 324–45.

Leonardo da Vinci on Painting: A Lost Book (Libro A) Reassembled from the Codex Vaticanus Urbinas 1270 and from the Codex Leicester by Carlo Pedretti. Berkeley. University of California Press, 1964.

Léonardo de Vinci ingénieur et architecte. Exh. cat. Montréal: Musee des Beaux-arts de Montréal, 1987.

Lomazzo, Giovanni Paolo *Trattato dell'arte della pittura, scultura et architettura*. Milan: Paolo Gottardo Pontio, 1585.

Lubke, Wilhelm. "Leonardo da Vinci als Architeckt." In *Kunstwerke under Kunstler*. Breslau (1888). 219 ff.

Ludwig, Heinrich, ed. *Leonardo da Vinci, Das Buch von der Malerei*. Vienna. W. Braumüller, 1882.

———, ed. *Lionardo da Vinci: Das Buch von der Malerei nach dem Codex Vaticanus 1270*. 3 vols. Vienna: Wilhelm Braumüller, 1882.

Macagno, Enzo. "Lagrangian and Eulerian Descriptions in the Flow Studies of Leonardo da Vinci." *Raccolta Vinciana* 24 (1992): 25.

Macagno, Matilde. "Geometry in Motion in the Manuscripts of Leonardo da Vinci." *Raccolta Vinciana* 26 (1995): 277–326.

———. "Transformation Geometry in the Manuscripts of Leonardo da Vinci." *Raccolta Vinciana* 26 (1995). 93–134.

Magni-Dufflocq, Enrico. "Da Vinci's Music." In *Leonardo da Vinci*. New York. Reynal, 1956.

Malaguzzi Valeri, Francesco. *La Corte di Ludovico il Moro II, Bramante e Leonardo da Vinci*. Milan. U. Hoepli, 1915.

———. *Leonardo da Vinci e la scultura*. Bologna: Nicola Zanichelli, 1922.

Marani, Pietro C. *Leonardo da Vinci. The Complete Paintings*. New York. Abrams, 2000.

———. *Leonardo e I leonardeschi nei musei della Lombardia (Guide artistiche Electa)*. Milan, Mondadori Electa, 1990.

Marani, Pietro C., and Pinin Brambilla Barcilon. *Leonardo: The Last Supper*. Chicago: University of Chicago Press, 2001.

Marinoni, Augusto. *Introduction to Leonardo da Vinci, Il codice atlantico della Biblioteca ambrosiana di Milano*, vol. 1. Florence. Giunti Barbera, 1975.

———. "Leonardo, Luca Pacioli e il 'de ludo geometrico.'" *Atti e Memorie della Reale Accademia Petrarca di Lettere, Arti e Scienze, 1970–72* 40 (1970–1972). 180–205.

Masters, Roger D. *Fortune Is a River: Leonardo da Vinci and Niccolò Machiavelli's Magnificent Dream to Change the Course of Florentine History*. New York: Simon and Schuster, 1998.

———. *Machiavelli, Leonardo, and the Science of Power*. Notre Dame, Ind.. University of Notre Dame Press, 1995.

McCurdy, Edward. *The Mind of Leonardo da Vinci*. London: Jonathan Cape, 1928.

———. *The Notebooks of Leonardo da Vinci*. New York: Reynal and Hitchcock, 1938.

McLanathan, Richard. *Images of the Universe. Leonardo da Vinci. The Artist and Scientist*. Garden City, N.J.. Doubleday, 1966.

Meyer, Barbara H., and Alice W. Glover. "Botany and Art in Leonardo's 'Leda and the Swan.'" *Leonardo* 22, no. 1 (1989): 75–82.

Moffatt, Constance, and Sara Taglialagamba, eds. *Illuminating Leonardo. A Festschrift for Carlo Pedretti*. Leiden: Brill, 2016.

Moffitt, John F. "Leonardo's 'Sala delle Asse' and the Primordial Origin of Architecture." *Arte Lombarda* 92–93, nos. 1–2 (1990): 76–90.

Morley, Brian. "The Plant Illustrations of Leonardo da Vinci." *Burlington Magazine* 131 (1979). 553–60.

Müller-Walde, Paul. *Leonardo da Vinci, Lebensskizze und Forsch ungen über sein Verhältniss zur Florentiner Kunst und zu Rafael*. Munich: G. Hirth, 1889.

Müntz, Eugene. *Léonard de Vinci, L'artiste, le penseur, le savant.* Paris: Hachette, 1899

Navoni, Marco, and Franco Buzzi. *Leonardo da Vinci and the Secrets of the Codex Atlanticus.* Vercelli. White Star, 2012

Nelson, Cami "From Sfumato to Transarchitectures and Osmose: Leonardo da Vinci's Virtual Reality." *Leonardo* 42, no 3 (2009): 259–64.

Nicholl, Charles. *Leonardo da Vinci: Flights of the Mind.* London. Penguin, 2005.

Nicodemi, Giorgio. *Leonardo da Vinci: Gemälde, Zeichnungen, Studien.* Zurich: Schweizer Druck und Verlagshaus, 1960.

Nuland, Sherwin B. *Leonardo da Vinci.* New York: Viking, 2000.

O'Malley, Charles D., and John Bertrand de. C. M. Saunders. *Leonardo da Vinci on the Human Body. The Anatomical, Physiological, and Embryological Drawings of Leonardo da Vinci. With Translations Emendations, and a Biographical Introduction.* New York: Henry Schuman, 1952.

O'Malley, Charles D , ed. *Leonardo's Legacy: An International Symposium.* Berkeley: University of California Press, 1969.

Ost, Hans. *Leonardo-Studien.* Berlin: De Gruyter, 1975.

Ottino della Chiesa, Angela. *L'opera completa di Leonardo da Vinci.* Milan· Rizzoli, 1967. Translated and republished as *The Complete Paintings of Leonardo da Vinci (Class of World Art).* London: Penguin, 1986.

Pacioli, Luca. *Divina Proportione.* Lexington, KY: Leopold, 2014 Facsimile of the original printing from 1509 in the Bibliothèque publique et universitaire de Genève.

Pater, Walter. *The Renaissance.* London· Macmillan, 1893.

Pauli, Jennifer, and Christopher Culwell. *Fodor's Guide to the Da Vinci Code.* New York: Fodor's, 2006

Pedretti, Carlo. *A Chronology of Leonardo da Vinci's Architectural Studies after 1500 In Appendix: A Letter to Pope Leo X on the Architecture of Ancient Rome.* Geneva: Librairie E. Droz, 1962.

———. *The Codex Hammer of Leonardo da Vinci.* Florence· Giunti Barbèra, 1987.

———. *Leonardo, Architect.* New York. Rizzoli, 1985.

———. *Leonardo, the Art of Drawing.* Florence: Giunti Barbèra, 2015.

———. *Leonardo. The Machines.* Florence. Giunti Barbèra, 1999.

———. *Leonardo. A Study in Chronology and Style.* Berkeley: University of California Press, 1973.

———. *Leonardo da Vinci.* Cobham, U.K.: Taj Books, 2005.

———. *Leonardo da Vinci. Fragments at Windsor Castle from the Codex Atlanticus.* London: Phaidon, 1957.

———. *Leonardo da Vinci. Nature Studies from the Royal Library at Windsor Castle.* Exh. cat. Introduction by Kenneth Clark. Houston. Museum of Fine Arts, 1982.

———. *Leonardo da Vinci: The Royal Palace at Romorantin.* Cambridge, Mass.. Harvard University Press/Belknap Press, 1972.

———. *Leonardo da Vinci and France: Château du Clos Lucé Parc Leonardo da Vinci, Amboise.* Florence: Poggio a Caiano, 2010.

———. *Leonardo da Vinci on Painting: A lost book (Libro A).* Berkeley: University of California Press, 1964.

———. "Leonardo on Curvilinear Perspective." *Bibliothèque d'humanisme et renaissance* 25 (1963). 69–87.

———. *The Literary Works of Leonardo da Vinci edited by J. P. Richter. Commentary.* Oxford, U.K.. Oxford University Press, 1977.

———, ed. *The Drawings and Miscellaneous Papers of Leonardo da Vinci at Windsor Castle.* New York. Harcourt Brace Jovanovich 1982.

———, ed. *Leonardo: Genius and Vision in the Land of the Marches,* bilingual ed. Florence: Cartei e Bianchi, 2005.

Perloff, Joseph K. "Human Dissection and the Science and Art of Leonardo da Vinci." *American Journal of Cardiology* 111, no. 5 (2013). 775–77.

Piumati, Giovanni, ed. *Il Codice Atlantico di Leonardo da Vinci nella Biblioteca Ambrosiana di Milano.* Milan: U. Hoepli, 1894–1904.

Pizzorusso, Ann. "Leonardo's Geology. The Authenticity of the Virgin of the Rocks." *Leonardo* 29, no. 3 (1996): 197–200.

Poggi, Giovanni, ed. *Leonardo da Vinci: La 'Vita' di Giorgio Vasari, nuovamente commentate e illustrata con 200 tavole.* Florence: L. Pampaloni, 1919.

Popham, Arthur E. *The Drawings of Leonardo da Vinci, Compiled, Introduced, and Annotated.* London: Jonathan Cape, 1946, 1952.

Popp, Anny E., ed. *Leonardo da Vinci: Zeichnungen.* Munich: Piper, 1928.

Randall, John Herman. "The Place of Leonardo da Vinci in the Emergence of Modern Science." *Journal of the History of Ideas* 14, no. 2 (April 1953). 191–202.

Raynham, Alex. *Leonardo da Vinci.* Oxford, U.K.: Oxford University Press, 2013.

Reeves, Gibson, and Carlo Pedretti. "Leonardo da Vinci's Drawings of the Surface Features of the Moon." *Journal for the History of Astronomy* 18 (1987): 55–58.

Reti, Ladislao. "Parting of Gold and Silver with Nitric Acid in a Page of the *Codex Atlanticus* of Leonardo da Vinci." *Isis: An International Review* 56, no. 3 (Fall 1965): 307–19.

Reti, Ladislao, ed. *The Unknown Leonardo.* New York: McGraw-Hill, 1974.

Richter, Irma A., and Martin Kemp. *Leonardo da Vinci's Notes (Oxford World's Classics).* Oxford, U.K.: Oxford University Press, 2008.

Richter, Jean Paul. *The Literary Works of Leonardo da Vinci, Compiled and Edited from the Original Manuscripts,* 2nd ed. 2 vols. Oxford, U.K.: Oxford University Press, 1939, 1970. First edition printed in 1883.

———, ed. *The Notebooks of Leonardo da Vinci,* vol. 1. Mineola, N.Y.: Dover Publications, 1970.

———, ed. *The Notebooks of Leonardo da Vinci,* vol. 2. Mineola, N.Y.: Dover Publications, 1970.

Rosheim, Mark. *Leonardo's Lost Robots.* New York: Springer, 2006.

Rosenberg, Adolf. *Leonardo da Vinci.* Leipzig: Velhagen and Klasing, 1924.

Routh, Shelagh, and Jonathan Routh. *Leonardo's Kitchen Notebooks: Leonardo da Vinci's Notes on Cookery and Table Etiquette.* London: Collins, 1987.

Rubin, Patricia Lee. "What Men Saw: Vasari's Life of Leonardo da Vinci and the Image of the Renaissance Artist." *Art History* 13 (1990). 34–46.

Rubin, Patricia Lee., et al. *Renaissance Florence: The Art of the 1470s.* Exh. cat. London: National Gallery Publications, 1999.

Sarton, George. *Six Wings: Men of Science in the Renaissance.* Bloomington. Indiana University Press, 1957.

Sassoon, Donald. *Becoming Mona Lisa: The Making of a Global Icon.* New York: Harcourt Brace Jovanovich, 2001.

———. *Mona Lisa. The History of the World's Most Famous Painting.* New York: HarperCollins, 2009.

Schapiro, Meyer. "Freud and Leonardo: An Art Historical Study." In *Theory and Philosophy of Art: Style, Artist, and Society.* New York: George Braziller, 1994.

Schofield, Richard. "Leonardo's Milanese Architecture: Career, Sources and Graphic Techniques." *Accademia Leonardi Vinci* 4 (1991). 111–57.

Scotti, Rita A. *Vanished Smile. The Mysterious Theft of Mona Lisa.* New York: Alfred A. Knopf, 2009.

Séailles, Gabriel. *Léonard de Vinci, L'artiste et le savant. Essai de Biographie Psychologique.* Paris: Perrin, 1892.

Seidlitz, Waldemar von. *Leonardo da Vinci, der Wendpunkt der Renaissance.* 2 vols. Berlin: J. Bard, 1909.

Sguaitamatti, Domenico, and Franco Giulio Brambilla. *The Last Supper, Leonardo da Vinci: The Masterpiece Revealed through High Technology.* Trans. Richard Pierce. Novara. White Star, 2013.

Shell, Janice, and Grazioso Sironi. "Salai and Leonardo's Legacy." *Burlington Magazine* 133, no. 1,055 (February 1991): 95–108.

Silverman, Peter. *Leonardo's Lost Princess. One Man's Quest to Authenticate an Unknown Portrait by Leonardo da Vinio.* Hoboken, N.J.: Wiley, 2012.

Smith, Webster. "Observations on the Mona Lisa Landscape." *Art Bulletin* 67 (June 1985): 183–99.

Solmi, Edmondo. "Le fonti manuscritti di Leonardo da Vinci." In *Giornale storico della letteratura italiana. Supplemento 10–11.* Florence: La nuova Italia, 1976. Originally published in Turin: Loescher, 1908

———. *Leonardo (1452–1519).* Florence. G. Barbèra, 1900.

Spike John, and David Alan Brown. *Leonardo da Vinci and the Idea of Beauty.* Exh cat. Muscarelle Museum of Art, Williamsburg, Virginia, and Museum of Fine Arts, Boston Florence: Centro Di, 2015.

Starnazzi, Carlo. *Leonardo: Acque e terre.* Introduction by Carlo Pedretti. Florence. Istituto Geografico Militare, 2008.

———. *Leonardo: Cartografo.* Introduction by Carlo Pedretti Florence: Istituto Geografico Militare, 2003.

———. *Leonardo: From Tuscany to the Loire.* Foligno: Cartei and Bianchi, 2008.

Steinberg, Leo. *Leonardo's Incessant Last Supper.* Boston: Zone Books, 2001.

Stites, Raymond S., and M. Elizabeth Stites. *Sublimations of Leonardo da Vinci: With a Translation of the 'Codex Trivulzianus.'* Washington, D.C.. Smithsonian Books, 1971

Strathern, Paul. *The Artist, the Philosopher, and the Warrior: Leonardo, Machiavelli, and Borgia—a Fateful Collusion.* London: Bantam, 2011

Suh, H. Anna, ed. *Leonardo's Notebooks. Writing and Art of the Great Master.* Boulder, Colo.: Black Dog and Leventhal, 2013

Suida Wilhelm *Leonardo und sein Kreis.* Munich: F. Bruckmann, 1929

Syson, Luke, et al. *Leonardo da Vinci. Painter at the Court of Milan.* Exh cat London: National Gallery, 2011.

Taglialagamba, Sara. *Leonardo and Anatomy.* Poggio a Caiano. CB Publishers, 2010.

———. *Leonardo and Architecture.* Poggio a Caiano: CB Publishers, 2010.

———. *Leonardo and Engineering.* Poggio a Caiano: CB Publishers, 2010.

———. *Leonardo and Nature.* Poggio a Caiano: CB Publishers, 2010.

Tasca, Ed *The Fables of Leonardo da Vinci. Based on Ideas and Drafts Annotated in da Vinci's Notebooks.* Johnson City, Tenn.: RoseHeart, 2017.

Thuis, Jens Peter. *Leonardo da Vinci: The Florentine Years of Leonardo and Verrocchio.* Trans. Jessie Muir. London: H. Jenkins, 1913.

Thro, E. Broydrick. "Leonardo da Vinci's Solution to the Problem of the Pinhole Camera." *Archives for the History of Exact Sciences* 48, nos. 3–4 (1994): 343–71.

Toni, Giovanni Battista De'. *Le piante e gli animali in Leonardo da Vinci.* Bologna: Nicola Zanichelli, 1922.

Turner, A. Richard. *Inventing Leonardo.* New York: Knopf, 1993.

———. *The Vision of Landscape in Renaissance Italy.* Princeton, N.J.: Princeton University Press, 1966.

Valentiner, Wilhelm Reinhold. "Leonardo as Verrocchio's Coworker." *Art Bulletin* 12, no. 1 (March 1930). 43–89.

Vallentin, Antonina. *Leonardo da Vinci: The Tragic Pursuit of Perfection.* New York. Viking, 1938.

Vasari, Giorgio. "Leonardo da Vinci." In *Le Vite de' piu eccellenti pittori, scultori ed architettori, nelle redazioni affrontate del 1550 e 1568,* 6 vols., ed. Rosanna Bettarini and Paola Barocchi, 186–212. Florence: Sansoni, 1966–1967.

Vecce, Carlo. *Leonardo.* Rome: Verbo, 1998, 2006.

Veltman, Kim H "Visualization and Perspective." In *Leonardo e l'età della ragione,* ed. Enrico Bellone and Paolo Rossi, trans. Giovanna Grandi, 185–201. Milan: Scientia, 1982.

Venerella, John. *The Manuscripts of Leonardo da Vinci in the Institut de France. Manuscript B.* Milan: Ente Raccolta Vinciana, 2003.

———. *The Manuscripts of Leonardo da Vinci in the Institut de France. Manuscript C.* Milan: Ente Raccolta Vinciana, 2001.

———. *The Manuscripts of Leonardo da Vinci in the Institut de France. Manuscript K.* Milan: Ente Raccolta Vinciana, 2004.

Venturi, Lionello. *La critica e l'arte di Leonardo da Vinci.* Bologna: Nicola Zanichelli, 1919.

Verga, Ettore. *Bibliographica Vinciana, 1493–1930.* Bologna. Nicola Zanichelli, 1931.

Vezzosi, Alessandro. *Leonardo da Vinci: The Mind of the Renaissance.* Trans. Alexandrea Bonfante-Warren. New York. Abrams, 1997.

Villata, Edoardo, ed. *Leonardo da Vinci. I documenti e le testimonianze contemporanee.* Milan: Castello Sforzesco, 1999

Waagen, Gustav Friedrich *Kunstwerke und Künstler in England und Paris.* 3 vols. Berlin: Nicolaischen Buchhandlung, 1837–1839.

Wallace, Robert. *The World of Leonardo, 1452–1519.* New York: Time, 1966.

Wasserman, Jack. "The Dating and Patronage of Leonardo's Burlington House Cartoon." *Art Bulletin* 53 (1971). 312–25.

———. *Leonardo da Vinci.* New York: Abrams, 2003.

Weidermann, Christiane. *Leonardo da Vinci.* New York: Prestel, 2010.

Wells, Francis C., and Martin Clayton. *The Heart of Leonardo: Renaissance Art and Modern Science.* London. Prestel, 2008.

White, Michael. *Leonardo: The First Scientist.* New York: St. Martin's, 2000.

Winternitz, Emanuel. *Leonardo da Vinci as a Musician.* New Haven, Conn.: Yale University Press, 1982.

Zöllner, Frank, and Johannes Nathan. *Leonardo da Vinci. The Complete Paintings and Drawings.* Cologne: Taschen, 2003.

———. *Leonardo da Vinci. The Graphic Work.* Cologne. Taschen, 2014.

Zubov, Vasilii Pavlovich. *Leonardo da Vinci.* Cambridge, Mass.. Harvard University Press, 1968.

Zwijnenberg, Robert. *The Writings and Drawings of Leonardo da Vinci. Chaos and Order in Early Modern Thought.* Trans. Caroline van Eck. Cambridge, U.K.: Cambridge University Press, 1999.

Index

About the Author

Allison Lee Palmer is professor of art history in the School of Visual Arts at the University of Oklahoma. She received her Ph.D. from Rutgers University with a dissertation titled "The Church of Gesù e Maria on the Via del Corso: Urban Planning in Baroque Rome," and her undergraduate degree in art history is from Mount Holyoke College. Palmer currently teaches undergraduate and graduate courses in art from the Renaissance through the 18th century, as well as interdisciplinary humanities courses for the College of Liberal Studies at the University of Oklahoma. Her teaching awards include the General Education Teaching Award (2012), the Irene and Julian J. Rothbaum Presidential Professor of Excellence in the Arts Award (2011), the School of Art Excellence in Teaching Award (2008), the College of Fine Arts Peer Recognition Award (2004), the College of Liberal Studies Superior Teaching Award (2002), and the Rufus G. Hall Faculty Award from the College of Liberal Studies (2001).

Palmer's published books include *Historical Dictionary of Architecture* (Rowman & Littlefield, second edition 2016, first edition 2008), *Historical Dictionary of Romantic Art and Architecture* (Scarecrow Press, 2011), and *Historical Dictionary of Neoclassical Art and Architecture* (Scarecrow Press, 2011). Her articles include "Lorenzo 'Spirito' Gualtieri's *Libro delle Sorti* in Renaissance Perugia," *Sixteenth Century Journal* 47, no. 3 (2016): 557–77; "The Story of *kolven* in the Study of Dutch Baroque Skating Scenes," *Notes on Early Modern Art* 2, no. 1 (March 2015): 21–30; "The *Last Supper* by Marcos Zapata (c. 1753): A Meal of Bread, Wine, and Guinea Pig," *Aurora: The Journal of the History of Art* 9 (2008): 54–73; "Sport and Art in Dutch Baroque Landscape Painting," *Proceedings of the North American Society for Sport History* (2007), 5–6; "The Image of the Risen Christ and the Art of the Roman Baroque Tabernacle," *Proceedings of the International Conference "Constructions of Death, Mourning and Memory,"* October 2006; "The Maternal Madonna in *Quattrocento* Florence: Social Ideals in the Family of the Patriarch," *Source: Notes in the History of Art* 21, no. 3 (Spring 2002): 7–14; "The Walters' *Madonna and Child* Plaquette and Private Devotional Art in Early Renaissance Italy," *Walters Art Journal* 59 (June 2001): 73–84; "Carlo Maratti's *Triumph of Clemency* in the Altieri Palace in Rome: Papal Iconography in a Domestic Audience Hall," *Source: Notes in the History of Art* 17, no. 4 (Summer 1998): 18–25; "Bonino da Campione's Monument of Bernabò Visconti and Equestrian Sculpture in the Late Middle Ages," *Arte Lombarda* 121, no. 3 (1997): 57–66; "The First Building Campaign of the Gesù e Maria on the Via del Corso in Rome: 1615–1636," *Architectura: Zeitschrift für Geschichte der Baukunst* 27, no. 1 (1997): 1–20; and "The Church of Gesù e Maria and Augustinian Construction during the Counter-Reformation," *Augustinian Studies* 28, no. 1 (1997): 111–40.